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RELEASE SITE PREDATION STUDY

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List of Abbreviations

ANOVA	Analysis of Variance
CDEC	California Data Exchange Center
CHTR	Collection, Handling, Transport, Release
Consortium	California Fish Tracking Consortium
CPUE	Catch Per Unit Effort
CVP	Central Valley Project
CWT	Coded Wire Tag
DIDSON	Dual Frequency Identification Sonar
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
DO	Dissolved Oxygen
EC	Electrical Conductivity
FCCL	UC Davis Fish Conservation and Culture Laboratory
FL	Fork Length
GPS	Global Positioning System
NMFS	National Marine Fisheries Service
HPR	Heading, Pitch, and Roll
PVC	Polyvinyl Chloride
SDFPF	John E. Skinner Delta Fish Protective Facility
SWP	State Water Project
TFCF	Tracy Fish Collection Facility
USBR	United States Bureau of Reclamation
USFWS	United States Fish and Wildlife Service
UTM	Universal Transverse Mercator
VAMP	Vernalis Adaptive Management Plan
VUE	VEMCO User Environment
WAAS	Wide Area Augmentation System

Executive Summary

The State Water Project (SWP) John E. Skinner Delta Fish Protective Facility (SDFPF; Figure 1) and federal Central Valley Project (CVP) Tracy Fish Collection Facility (TFCF) were constructed in the late 1950's and 1960's to salvage fish entrained at the southern Sacramento-San Joaquin Delta (Delta) water export facilities. These facilities protect fish by using a series of behavioral dewatering louvers to concentrate fish into holding tanks where they are held for later transport back into the Delta away from the zone of influence of the water export facilities. Fish are held in these facilities until they are collected by draining each holding tank into a haul-out bucket (collection), transferred to a water tanker truck (handling), transported to release sites in the central Delta near the confluence of the Sacramento and San Joaquin Rivers (transport), and released back into the Delta at fixed release points (release; Figures 2 & 3).

In response to concerns about the survival of sensitive fish species exposed to the Collection, Handling, Transport, and Release (CHTR) processes at the state and federal delta water export facilities, the California Department of Water Resources (DWR) in collaboration with the California Department of Fish and Game (DFG) and U.S. Bureau of Reclamation (USBR) conducted a series of focused investigations on the CHTR phase of the salvage process. These investigations were developed to provide useful information that could serve to reduce the potential vulnerability of sensitive fish species including delta smelt (*Hypomesus transpacificus*) and Chinook salmon (*Oncorhynchus tshawytscha*) to injury and mortality during the salvage process. The results of these investigations will be used to reduce overall mortality and stress during the salvage process by making recommendations and providing baseline information for the improvement of existing salvaged fish release sites and construction of new release sites.

The Department of Water Resources' contribution to this effort was to conduct a focused investigation into the release stage of the fish salvage process at the SDFPF. The release phase investigation was composed of three separate elements, each investigating a different aspect of the release phase. Element 1: an investigation of the far-field survival of salvaged fish following release, Element 2: an investigation of release site predation, and Element 3: an investigation of the physical factors influencing mortality and injury during release. The Element 1 investigation was subsequently eliminated based on peer review comments, while the results of the Element 3 investigation will be available as a separate technical report. The results of the Element 2-Release Site Predation Study are the focus of this report.

Element 2- Release Site Predation

Fish released at the salvaged fish release sites into the Delta may experience high mortality because of predation by piscivorous fish and birds. The concentration of fish at the release sites may attract and concentrate predators in the receiving waters at the release locations. Anecdotal observations by recreational anglers have also indicated that predatory fish are concentrated near the release locations, and field observations have documented the attraction of predatory birds to the areas during the release of salvaged fish.

The experimental design, methods, and approach for evaluating predator abundance and behavior within the receiving waters at the existing release sites included five different, but interrelated, study methods: predator sampling (electrofishing and avian predation observations), mark-recapture (acoustic & Floy tagging), Dual Frequency Identification Sonar (DIDSON) acoustic camera observations, hydroacoustics, and a hypothetical predation risk analysis driven by bioenergetics. Monitoring was conducted during five different periods (from August 2007 until April 2008) at the SWP fish release site at Horseshoe Bend on the Sacramento River and two reference/control sites along Horseshoe Bend. Monitoring consisted of using the DIDSON camera, electrofishing, avian predator observations, and Floy/acoustic tagging. These monitoring techniques were also conducted to varying degrees at other salvaged fish release sites in the Delta.

Electrofishing showed that the predator composition at the Horseshoe Bend release site included various fish species, notably largemouth bass (*Micropterus salmoides*), Sacramento pikeminnow (*Ptychocheilus grandis*), and striped bass (*Morone saxatilis*). Catch per unit effort (CPUE) in the vicinity of the release site was highest for largemouth bass, though they were predominantly captured near the shoreline and not directly at the end of the fish release pipe. Given their piscivorous nature and substantial population near the release site, it is possible that while they may not feed directly on fish exiting the release pipe, the largemouth bass may feed on salvaged fish that disperse following release. Conversely, Sacramento pikeminnow and striped bass were the predominant piscivores captured directly at the end of the release pipe. CPUE for Sacramento pikeminnow was generally lower than that of largemouth bass, but higher than striped bass numbers at all sites.

Floy and acoustic tags were used to determine site fidelity. Largemouth bass were Floy tagged and through recapture were shown to exhibit strong site fidelity. Although largemouth bass were not tagged with acoustic tags, several striped bass and Sacramento pikeminnow were tagged with acoustic telemetry tags to examine their site fidelity and coarse scale movements. Striped bass did not exhibit strong site fidelity, remaining near a release site for only a few days or less. Conversely, some Sacramento pikeminnow showed strong site fidelity, remaining nearby a release site for as long as four months. Individuals of both species were recorded making long migrations up and down the Sacramento-San Joaquin watershed with striped bass generally detected moving downstream towards San Pablo Bay and Sacramento pikeminnow generally moving upstream in the Sacramento River. Sacramento pikeminnow were detected as far upstream as the Ord Ferry Road Bridge, and striped bass were detected as far downstream as Mare Island in San Pablo Bay.

The DIDSON camera, which provides video imagery in dark or turbid water, was used to record observations of near-field predatory fish relative abundance and behavior at three of the release sites and two control sites. The DIDSON observations showed aggregations of fish at the SWP Horseshoe Bend release site during the summer, fall, late-fall, and early spring when salvage was highest. Conversely, fewer predatory fish were observed during the winter when few fish were being salvaged and released. Observations at the SWP Curtis Landing and CVP Emmaton release sites revealed similar aggregations of predatory fish, though the aggregations were often smaller than at the SWP Horseshoe Bend release site. While the reason for the smaller aggregations was unclear, it was most likely a function of pipe designs and locations. Conversely, the two control sites located along Horseshoe Bend consistently had few if any predator sized fish present during DIDSON monitoring.

DIDSON observations revealed that predatory fish effectively exploit salvaged fish releases by holding at the end of the release pipe and capturing prey fish as they exited the pipe. DIDSON observations however, did not reveal any evidence of attraction to specific components of the release process (e.g. flushing pump activation). Rather, predators were seen remaining aggregated for long periods during non-release periods and exhibiting milling behavior. This may have been a result of some salvaged fish being trapped in the release pipe from prior releases, and slowly trickling out of the pipe over an extended period of time. Predatory fish were also observed utilizing debris trapped on the pier pilings at the release site as cover/refuge. Observations showed predatory fish rapidly dart out of the trapped debris and feed on salvaged fish a short distance away. As remedial measures for these observations, efforts are currently underway to remove the trapped debris and increase the capacity of the flushing pump in an effort to reduce predator habitat and prevent salvaged fish from becoming entrapped in the release pipe.

Hydroacoustic sonar data revealed that the reach of river including the SWP Horseshoe Bend release site did not have substantially more predators than similar control sites located further upstream in Horseshoe Bend. In fact, one of the control sites had substantially more predator sized fish than the release site. The reason for this disparity with DIDSON observations might be due to the sampling range of the two types of equipment and the numbers of fish being released at the release site. The DIDSON has a very small field of view and samples only a small volume of water, while the hydroacoustics has a much longer range and samples a large volume of water. As a result, the DIDSON was able to detect only the presence or absence of predatory fish within a couple meters of the sites, while the hydroacoustics equipment detected predatory fish abundance over a larger area. Nevertheless, the hydroacoustic data and DIDSON observations indicate that when releases are consistently large, a group of predatory fish is consistently observed near the fish release pipe. The predators observed using the DIDSON were likely fish that were actively feeding, as confirmed by the hydroacoustics. In addition, the hydroacoustics data was able to show seasonal differences in predator abundance. This was likely a result of few fish being salvaged and released, and a corresponding inconsistent food supply for predatory fish. Instead the predatory fish dispersed into the nearby area where they were sampled with the hydroacoustics but not the DIDSON.

When coupled with a bioenergetics model, the hydroacoustic data was used to determine the potential ratio of salvaged fish biomass released to salvaged fish biomass potentially consumed (by predatory fishes) occurring at the SWP Horseshoe Bend release site. Based on the bioenergetics approach, when few salvaged fish are released (<2,000, assuming 13-grams each), the predatory fish population can theoretically consume more than 10% of the fish being released. Conversely, when salvaged fish numbers are highest during the summer, the amount of biomass released is sufficient to effectively exceed the predatory fish population food demand potentially resulting in less predation. These results suggest that the magnitude of predation mortality at the release sites is strongly dependent upon the season and amount of biomass being salvaged and released. Furthermore, these results suggest that the practice of making relatively small and frequent releases of salvaged fish to reduce the stress and mortality associated with holding may have the unintended consequence of resulting in an increased rate of predation mortality.

The results of the avian predation survey showed that cormorants and gulls are the predominant avian predators on salvaged fish. Both species were observed feeding on salvaged fish at the SWP Horseshoe Bend release site including DIDSON footage of cormorants actively chasing and capturing salvaged fish as they exited the release pipe. Gull populations were highest earlier during the study (summer/fall), while cormorants were more common near the end of the study (winter/spring). Significantly more avian predators were observed at the SWP Horseshoe Bend release site and CVP Emmaton release site than at either of the control sites. Piscivorous birds were generally rare and were not observed feeding at the control sites or at the SWP Curtis Landing release site. At the SWP Horseshoe Bend release site, birds were routinely observed exploiting an elevated agricultural intake structure as a resting and observation spot before and after salvaged fish releases. Consequently, as a remedial measure to reduce avian predation on salvaged fish, bird deterrents were placed on the agricultural intake structure to prevent further exploitation of the structure for feeding purposes. At the CVP Emmaton site, birds were also observed perched on the railing for the catwalk extending out to the end of the pipe. Given their large metabolic demands, even a few piscivorous birds may be capable of having a substantial predation effect by potentially consuming large numbers of salvaged fish.

Results of the release site predation monitoring suggest that predation at the release site by several species of fish and birds could have a substantial effect on the number of fish surviving the release phase of the salvage process depending on the season and amount of biomass being salvaged and released. Since salvage rates may vary dramatically from day to day, no attempt was made to estimate an exact rate of predation mortality. Rather a series of estimates of potential prey consumption by predators based on predator species and time of year (bioenergetics) was developed. These estimates could be used to calculate the potential vulnerability to predation of a specific amount of biomass being salvaged and released. A series of recommendations and future research questions are also outlined in this report with the goal of reducing release site predation through modifications of the existing release sites and guidelines for the site selection and design of new release sites. Efforts are currently under development to implement these recommendations in compliance with the 2009 National Marine Fisheries Service Biological Opinion for SWP/CVP operations which calls for a reduction of release site predation by 50 percent.

1.0 Introduction

The John E. Skinner Delta Fish Protective Facility (Figures 1 & 2) was built in the 1960s and designed to protect fish in the Sacramento-San Joaquin Delta from entrainment into the California Aqueduct. The fish facility was designed with a maximum louver screening capacity of 291 m^3/s (10,300 cfs). Screened fish are bypassed into holding tanks from which they are loaded into tanker trucks for transport to release sites outside the zone of influence of the South Delta water diversions. Water and fish diverted from Old River enter Clifton Court Forebay, which is used as a regulating reservoir for the pumping plant. The water and fish drawn from the forebay first travel by an intake channel to a floating trash boom designed to intercept floating debris and guide it to a trash conveyor. Water and fish then flow through a trash rack to a series of louvers arranged in a Vee pattern. The louvers create a disturbance in the water to guide fish into the SDFPF. In the final stage of the fish salvage process, salvaged fish are then collected, handled, transported away from the influence of the export pumps, and released back into the Delta in a process known as Collection, Handling, Transport and Release (CHTR).

Figure 1-Aerial view of the John E. Skinner Delta Fish Protective Facility (SDFPF) including the Primary Louvers arranged in a Vee configuration

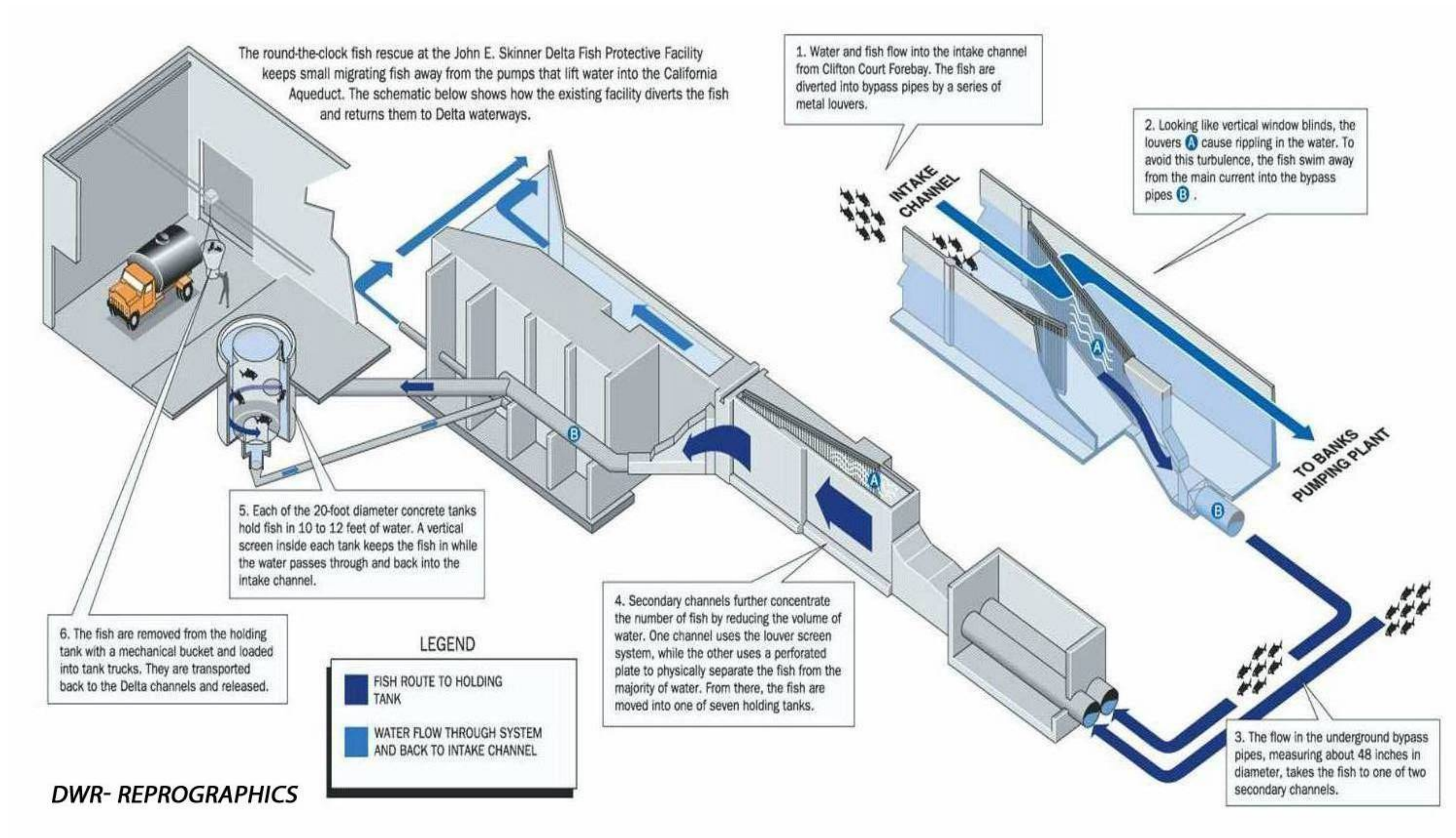


Figure 2-The fish salvage process at the SDFPF

Fish released at the salvaged fish release sites (Figure 3) into the Delta may experience high mortality because of predation by piscivorous fish and birds. During the salvage process, fish are concentrated in a relatively small area immediately after release and may be disoriented by hydraulic turbulence as water and fish are released at a relatively high velocity through the release pipe (DWR 2005). The concentration of dead or injured fish at the release sites may attract and concentrate predators in the receiving waters at the release locations. Anecdotal observations by recreational anglers have indicated that predatory fish are concentrated near the release locations, and field observations have documented the attraction of predatory birds to the areas during the release of salvaged fish (DWR 2005). Several studies have also documented predation mortality associated with the fish salvage operations at both the SWP and CVP (Delta Fish Facilities Technical Coordinating Committee 1980, Kano 1987, DFG 1984, Fausch 2000, Willis and others 1994) and at locations in the Delta receiving waters (Pickard and others 1982). However, actual losses resulting from predation mortality by both fish and birds following release at the salvaged fish release sites are uncertain.

The 2000 CALFED Record of Decision identified the improvement or replacement of the existing fish salvage facilities of the State and Federal export facilities as a major objective to restore and protect fisheries resources (CALFED 2000a, 2000b). However, while proposed new screening facilities would have significant design improvements, a new or modified CHTR process may still be required to move salvaged fish away from the influence of the export facilities. Concerns that these CHTR processes may decrease survival of salvaged delta smelt and other sensitive fish species, which would limit the benefits of new fish screening facilities, led to a comprehensive program designed to investigate the impacts of the CHTR process and assess the potential benefits of new CHTR technologies at the state and federal water export facilities. The Interagency Ecological Program (IEP) and Central Valley Fish Facilities Review Team (CVFFRT) coordinated a series of collaborative studies designed to investigate the effectiveness of the existing fish salvage process and assess the potential benefits of new CHTR technologies at the state and federal water export facilities. The Department of Water Resources' contribution to this effort was to conduct a focused investigation into the release stage of the fish salvage process at the SDFPF. The objective of this investigation, funded by Proposition 13 bond funds and conducted with support from DFG and USBR, was to determine the survival of salvaged fish being released at the existing fish release sites and to gather the necessary scientific and engineering information for the design and operation of improved fish release facilities. The investigations focused on:

1. A comprehensive evaluation of the effects of specific components of the release stage of the salvage process on the survival of delta smelt and other species of concern including physical aspects of the release procedure
2. Collecting necessary scientific information for use in evaluating potential

alternative technologies designed to reduce stress and improve survival throughout the release stage of the salvage process

3. Developing criteria for the design of new facilities or large-scale improvements to the existing release facilities

Originally, the release stage investigation had three separate elements. Element 1– an assessment of the far-field survival of salvaged fish released at both the SWP and CVP releases sites; Element 2 – examination of the abundance, composition, and behavior of predators in the receiving waters at the release sites; and Element 3 – an evaluation of the physical factors influencing mortality and injury of fish during release. The following provides a brief description of these investigations:

- Element 1 was proposed as an assessment of the far-field survival of salvaged fish following release. It was designed to develop quantitative estimates of survival of juvenile fish experimentally released at both the SWP and CVP release sites and at control sites. The experimental design of Element 1 included mass releases of Coded Wire Tagged juvenile Chinook salmon at each salvaged fish release site and at control sites with subsequent recapture downstream using a Kodiak Trawl. Element 1 was subsequently eliminated based on IEP Management Team and peer reviewer concerns about potentially low recovery rates of marked fish using the proposed or existing trawl sampling methodology.

- Element 2, the Release Site Predation Study presented in this report, examined the abundance, composition, and behavior of predators in the receiving waters at the release sites. This study involved using multiple survey methods including electrofishing and avian point counts to determine predator composition. The study included mark-recapture using Floy and acoustic tagging to determine site fidelity along with DIDSON and hydroacoustic sonar observations to determine predator behavior and abundance. In addition, a hypothetical predation risk analysis was performed using a bioenergetics approach.

- Element 3 was designed to assess the physical factors influencing mortality of fish during release. This study assessed the survival and injury of salvaged fish as they exited the release truck and traveled down a near full scale replica release pipe. It included an evaluation of the hydraulic forces and debris loads associated with the release stage including release pipe hydraulics, release pipe design, and the effect of debris on sensitive salvaged fish species. The results of the Element 3 investigation are presented in a separate report, but generally concluded that survival of sensitive fish (adult delta smelt and juvenile Chinook salmon) through the release stage is high and was not significantly different from control treatments regardless of debris loading (DWR 2010).

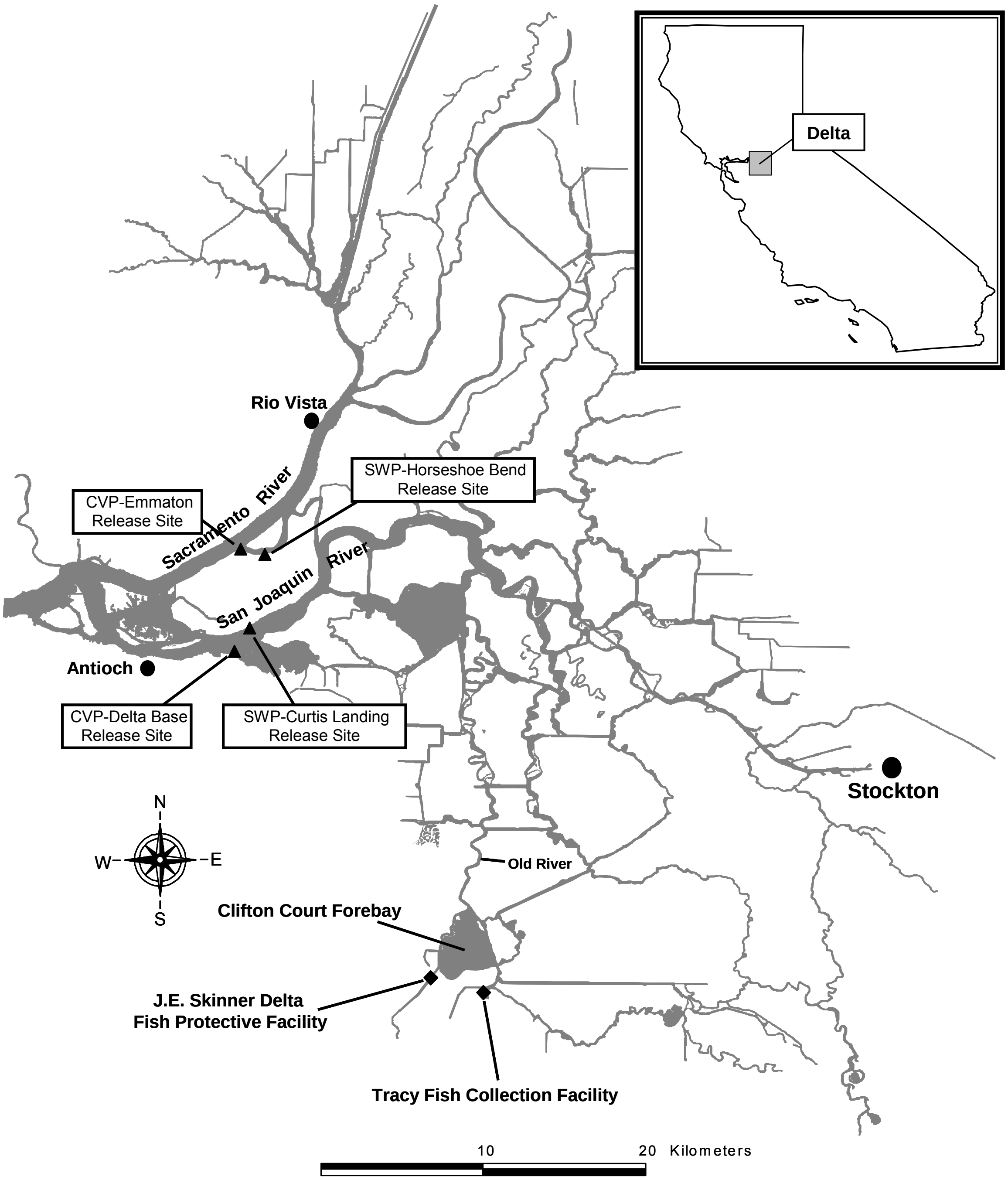


Figure 3- Map of the SWP and CVP fish salvage facilities and release sites. The release sites are a 45- to 60-minute drive from the salvage facilities.

1.1 Objective

The primary objective of the Release Site Predation Study was to develop quantitative and qualitative information for use in assessing the potential magnitude of predation mortality in the receiving waters at the release sites. The study was intended to provide additional information on the distribution and behavior of predatory fish at the release sites. However, the field studies focused primarily on the SWP Horseshoe Bend release site. Another intention of the study was to provide the necessary scientific and technical information for assessing predation as a factor affecting survival of salvaged fish. In the event that predation mortality was identified as a significant factor, the results would provide a foundation of information useful in identifying and evaluating potential alternative technologies designed to reduce or avoid predation mortality of released fish.

1.1.1 Research Questions in Detail

A number of questions exist regarding the potential magnitude and severity of predation mortality as a factor influencing overall survival of fish salvaged at the SWP and CVP and returned to the Delta estuary. These research questions include:

- Is predation mortality in the receiving waters a biologically significant contribution to overall mortality of salvaged fish?
- What are the species of predatory fish and birds inhabiting the Delta estuary, on a seasonal basis, at each of the designated release sites?
- What is the density and geographic distribution of predatory fish in the receiving waters at each release site and does the abundance and distribution of predators change before, during, and after the release of salvaged fish?
- How does predation on salvaged fish vary in response to environmental conditions?
- Are predatory fish behaviorally attracted to the receiving waters at one or more of the designated release sites, and is there evidence of learned behavior contributing to the attraction of predators?

1.2 Experimental Design and Approach

The experimental design and approach for evaluating predation within the receiving waters at the existing release sites includes five different, but interrelated, study methods including:

1) Sampling to determine predator species composition (electrofishing and piscivorous bird surveys)

2) DIDSON camera observations of near-field predator behavior

3) Hydroacoustic determination of predator abundance, distribution, and behavioral attraction

4) Mark recapture using Floy and Acoustic tagging to examine predator movement (e.g., site fidelity, behavioral attraction) in response to releases

5) A hypothetical predation risk analysis using a bioenergetics model

1.2.1 Study Area

There are four active sites for the release of salvaged fish in the Delta (Figure 4). The active release sites include the SWP release sites on Sherman Island, one at Horseshoe Bend (SWP Horseshoe Bend) and one on the lower San Joaquin River (SWP Curtis Landing). The CVP release sites are at the bifurcation between Horseshoe Bend and the Sacramento River (CVP Emmaton) and on the lower San Joaquin River at the Antioch Bridge (CVP Delta Base). The frequency of releases vary based on a number of factors including the seasonal densities and patterns of fish collected in salvage operations, debris loading, maximum fish holding times as specified in federal biological opinions, and diversion operations. The frequency of releases per site also varies, but generally does not exceed twice per day per site during routine operations. For the purposes of this study we also selected two reference or “control” sites, both on Horseshoe Bend in the Sacramento River (Figure 4). We selected two water intake structures because they are ubiquitous structures in the delta. These two specific sites were also chosen based on their proximity to the SWP Horseshoe Bend release site (both are within Horseshoe Bend) and similar habitat and underwater structure (pilings and underwater pipes).

Hydroacoustic surveys were conducted at the SWP Horseshoe Bend release site and the control sites. DIDSON surveys were conducted at all the sites with the exception of the CVP Delta Base site which was deemed unsafe for monitoring due to significant underwater hazards (fishing line). For the acoustic telemetry aspect of this study, a grid of receivers was maintained that included all the release and control sites in addition to several other monitors up and down the Sacramento River (see acoustic telemetry section). Additionally, data from receivers maintained by the various agencies of the California Fish Tracking Consortium (californiafishtracking.ucdavis.edu), including several receivers maintained by the study team at the SWP export facilities, were available to analyze large scale movement of tagged fish.

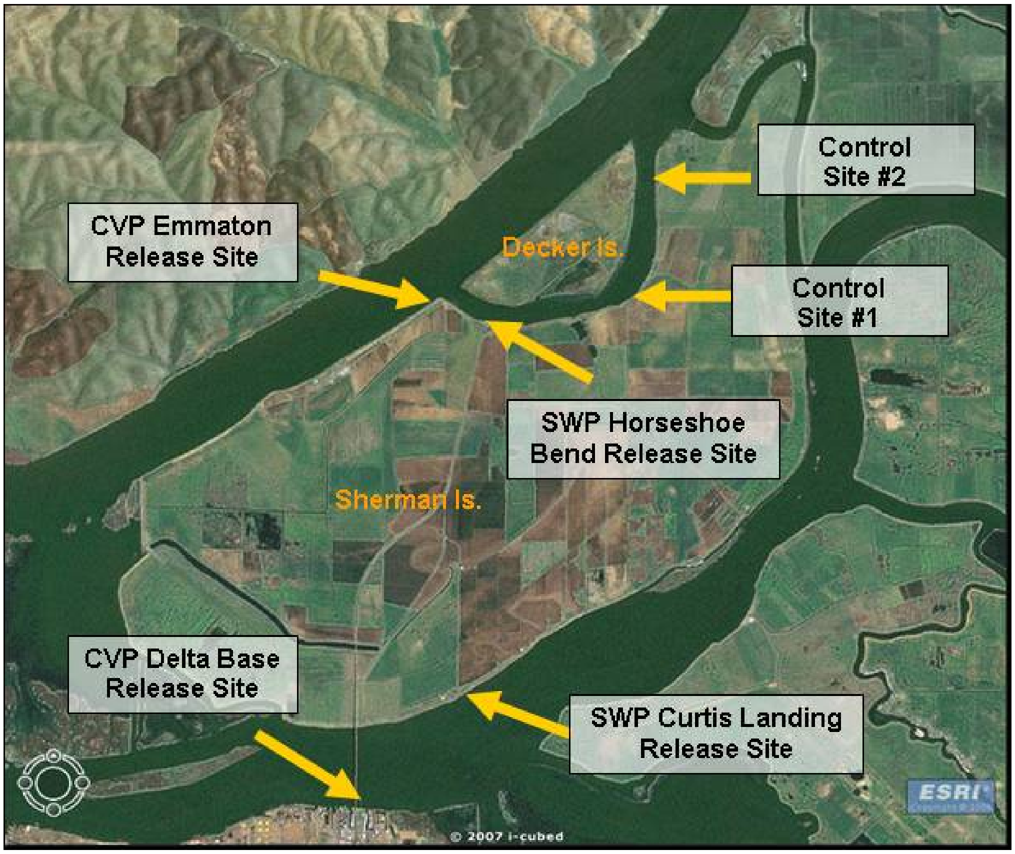


Figure 4- Map of Horseshoe Bend and the surrounding areas with study sites indicated

SWP Horseshoe Bend Release Site

The SWP Horseshoe Bend release site is located within Horseshoe Bend on Sherman Island, approximately 11 km (6.8 mi) downstream of the city of Rio Vista along highway 160. The release facility consists of two 30.5-cm (12-in) diameter steel pipes (Figure 5). One pipe is approximately 54.3 m (178 ft) long and is used for the release of fish. The other pipe houses a submersible pump which feeds flushing water at 0.005 m^3/s (0.18 cfs) into the release pipe through a four inlet manifold. The pipelines are fixed to the top of the Sherman Island levee at approximately a 16% slope with a straight trajectory into the water and are supported by a series of steel piles. The end of the release pipeline extends 2 m (6 ft) beyond the last set of piles and is suspended 1.8 m (6 ft) above the channel bottom to prevent blockage due to sediment buildup. At the mean high water level, the pipe is submerged 3.7 m (12 ft). The flushing system and other release components of the release stage during the CHTR process are discussed in detail in the Element 3 investigation report. The SWP Horseshoe Bend site is operated on an alternative basis with the SWP Curtis Landing site.

Figure 5- SWP Horseshoe Bend release site on Sherman Island

SWP Curtis Landing Release Site

The SWP Curtis Landing release site is on the San Joaquin River side of Sherman Island, immediately upstream of the Antioch Bridge. The mean water depth at the end of the release pipe is approximately 4.5 m (15 ft) and the pipe extends approximately 9 m (29.5 ft) from the shoreline into the river channel (Figure 6). This site is unique in that it has a 162° elbow after the first 4.5 m (15 ft) of pipe, changing the slope of the pipe from a shallow 4.8% to a much steeper 22.5%. Like the SWP Horseshoe Bend release site, the Curtis Landing release site is equipped with a pipe flushing system with a flow rate of 0.005 m^3/s (0.18 cfs). There is an abandoned line of pilings adjacent to the shoreline that are mostly submerged as well as a small tree growing on a small island just upstream (~20 m) of the release pipe. Additionally there is a private dock with pilings ~30 m (98.5 ft) downstream of the release pipe and extending ~10 m (33 ft) into the river. The SWP Curtis Landing release site is operated on an alternative basis with the SWP Horseshoe Bend release site, unless the release occurs at night as this site is unfenced and deemed unsafe for night time operations. The site includes a single inlet flushing manifold and rinse down system that is operated similarly to the SWP Horseshoe Bend release system.

Figure 6- The SWP Curtis Landing Release Site with the release pipe extending down into the water. The smaller pipe on the right is the pipe and pump system supplying the flushing flow.

CVP Emmaton Release Site

The CVP Emmaton release site is located on the Sacramento R. side of Sherman Island at the downstream mouth of Horseshoe Bend (Figure 7). It is located 0.8 km (0.5 mi) downstream of the SWP Horseshoe Bend release site. The release site consists of four pipes that extend to various depths in the channel with a catwalk and piling structure that extends to the end of the longest pipe. There is a permanent water quality station housed in a small shed at the end of the catwalk. Two of the four pipes at the release site are pump/water supply lines that provide a flushing/rinsing flow of 0.045 m^3/s (1.6 cfs). The flushing system is equipped with a timer that randomly turns the pump on and off 4 times each day for 10 minutes each time. The remaining two pipes are the fish release pipes situated at approximately a 36% slope. The longer of the two fish release pipes extends approximately 25 m (82 ft) into the river and has a mean depth at the pipe outlet of about 7.3 m (24 ft), while the other shorter pipe extends roughly half that length and depth and is operated in order to reduce clogging problems when high debris levels are present in the transport truck. The shoreline consists of sparsely vegetated riprap on both sides. The CVP

Emmaton site is operated on an alternative basis with the CVP Delta Base Site.

Figure 7- The CVP Emmaton release site

CVP Delta Base

The second CVP release site is on the south bank of the San Joaquin River near the Antioch Bridge. It is in a park behind an East Bay Regional Parks maintenance yard in a fenced compound. This site is similar in detail to the CVP Emmaton release site including the same flushing system (0.045 m^3/s pump with timer). The San Joaquin River is much shallower and wider at the Antioch Bridge site than the channel at the CVP Emmaton release site. Consequently, the release pipe is longer (58 m [190 ft]), has a shallower slope (18%, Figure 8), and has a mean depth at the pipe outlet of approximately 4.5 m (15 ft).

Figure 8- The CVP Delta Base Release Site

Control Site 1

Control Site 1 is located within Horseshoe Bend on the Sacramento River 0.8 km (0.5 mi) upstream of the SWP Horseshoe Bend release site. The site consists of a water intake structure with pilings and a cylindrical fish screen that serves as the primary water intake for Sherman Island. The shoreline is heavily vegetated with tules and overhanging trees (Figure 9).

Figure 9- Control Site 1, a screened water diversion on Sherman Island

Control Site 2

Control Site 2 is also located within Horseshoe Bend on the Sacramento River. It is 0.8 km (0.5 mi) upstream from Control Site 1 and 1.6 km (1 mi) upstream from the SWP Horseshoe Bend release site. The site consists of an unscreened water intake structure with pilings and a pump platform. The shoreline is heavily vegetated with tules and submerged aquatic vegetation extending out to the platform (Figure 10).

Figure 10- Control Site 2, an unscreened water diversion on Sherman Island

1.2.2 Study Period

The Release Site Predation Study involved periodic monitoring throughout the year to cover a range of seasonal and operational conditions. As per the original plan, monitoring was to commence in the late spring of 2007. However, due to export restrictions imposed by the presence of listed delta smelt in the South Delta, the first scheduled monitoring period in late May/early June was cancelled. The export restrictions included a 10 day halt in pumping which resulted in a cessation of salvage operations. As a result, monitoring commenced in August 2007 and ended in early April 2008 (Table 1). Each monitoring event typically consisted of two to three weeks of DIDSON, Hydroacoustic, and avian predation monitoring. Ten full days of monitoring were scheduled in the study plan, but due to weather resulting in missed monitoring days, each 10-day DIDSON/Hydroacoustic monitoring period took as long as three weeks. Each two-to-three-week monitoring event was followed by one week of electrofishing and fish tagging. Telemetry receivers were deployed beginning in May of 2007 and were periodically serviced and downloaded for the duration of the study (see Acoustic Tagging section).

Table 1- Monitoring schedule for the Release Site Predation Study

Monitoring Period	Date
1	August 1, 2007– August 31, 2007
2	October 3, 2007 – October 29, 2007
3	November 26, 2007 – December 21, 2007
4	January 28, 2008 – February 26, 2008
5	March 10, 2008 – April 2, 2008

Note: An additional monitoring period was planned for May/June 2007, but was cancelled due to SWP export restrictions due to delta smelt salvage

1.3 Assumptions of the Study Plan

Fundamental assumptions of the predation study included, but were not limited to:

- The receiving waters were defined as within 50-m (165-ft) of the end of the release pipe. This area was arbitrarily set based on sampling gear limitations and lack of previous information on the spatial distribution of predator fish in the study area.
- Preliminary field pilot observations at the release sites using the DIDSON camera suggested that predatory fish aggregate near the end of the release pipe.
- Field data collection efforts as part of this investigation did not change or alter the density or distribution of predatory fish or birds in the receiving waters.
- For this investigation, control locations were selected that were assumed to be representative of the habitat conditions, baseline food availability, and structural components of a release site. The control locations are both water intake structures, including multiple pipes, and surrounding pilings approximately 1.6 km (1 mi) and 0.8 km (0.5 mi) upstream of the SWP release site within Horseshoe Bend, respectively.
- The study assumed that the control sites were far enough away from the release sites that the release sites would not affect the local abundance of predators at the control sites. Since predators can move upstream and downstream their abundance could be elevated over distant areas. However, a desire to select sites with similar habitat conditions and structural components resulted in limiting selection of control sites within Horseshoe Bend.

- The experimental study assumed that predator response and distribution at the control sites was representative of conditions occurring at the SWP Horseshoe Bend release site and can be used on a comparative basis to evaluate the results of field studies and observations at other release sites. Based on similarities in water depths and velocities, the control locations and the SWP Horseshoe Bend release site habitat and environmental conditions appeared to be similar. Water depths and velocities, at the control sites, however, differed from environmental conditions occurring at the CVP Sacramento River (Emmaton) release site and SWP and CVP San Joaquin River sites (Curtis Landing and Delta Base).

1.4 Limitations of the Study Plan

Fundamental limitations of the predation study included:

- Given the difficulties of field data collection and observations, the differential vulnerability, predation, or mortality of salvaged fish cannot be readily determined by this study because the data collection methods do not differentiate between predation on different prey species or between live, dying, or dead fish.
- A wide variety of environmental and biological variables influence predator dynamics in the receiving waters. However, the experimental field investigations were simplified to focus on specific parameters and biological responses in order to keep the study at a manageable scale.
- This study was not intended to address any potential ecological effects resulting from salvage operations (e.g. the long-term survival of listed species), but rather focused on assessing the survival of all salvaged fish.
- Measurements of fish lengths were only conducted using the hydroacoustics system and electroshocking. While the DIDSON includes a software measuring tool, no published literature was located documenting the accuracy of measurements attained using this software.

1.5 Project Responsibilities and Coordination

This study was conducted as a collaborative effort between biologists and engineers of the California Department of Water Resources (DWR), U.S. Bureau of Reclamation (USBR), and California Department of Fish and Game (DFG). The following describes each agency’s role and responsibilities:

- The California Department of Water Resources was the lead agency. The DWR Fishery Improvements Section was responsible for project management, coordinating with the multi-agency technical teams, completing the DIDSON and avian predation components of this study, and writing the final report.

- The USBR Fisheries and Wildlife Resources Group provided technical support and was responsible for the hydroacoustics component of this study, data analysis and interpretation, and report writing.
- The DFG Fish Facilities Research Unit provided technical support and was responsible for electrofishing/sampling at the release and control sites, tagging predatory fish, operating and maintaining the acoustic tracking receiver network, data analysis and interpretation, and report writing.

2.0 Predator Composition and Mark-Recapture

Several techniques were employed to determine species composition and behavior at the SWP salvaged fish release sites at Horseshoe Bend and Curtis Landing and two control sites located upriver of the Horseshoe Bend site (Figure 4). These techniques included electrofishing and mark-recapture using acoustic telemetry and Floy tagging.

Sampling at the SWP salvaged release sites and two control sites using an electrofishing boat occurred once every two months during each of the monitoring periods. Typically, sampling was performed at the end of each monitoring period, so as not to interfere with other data collection methods (DIDSON and Hydroacoustics).

2.1 Materials and Methods

2.1.1 Electrofishing

Electrofishing was used to collect fish in the receiving waters and surrounding shoreline areas to determine species composition and relative abundance (catch per unit effort: CPUE) for each location. Sampling was performed using an electrofishing vessel (model SR-18EH) built by Smith-Root, Inc. (Vancouver, WA). This vessel was configured with a 5.0 Generator Powered Pulsator (5.0 GPP) Electrofisher. This system was powered using a Smith-Root modified Honda generator with a rated output power of 5,000 watts and a direct current output peak of 1,000 volts. Current was applied to the water using two Smith-Root anodes (model SAA-6). The anode design featured six stainless steel dropper cables that were submersible to about 0.9 to 1.2 m (3–4 ft) of water. Each anode was clipped to a boom arm on the vessel's port and starboard sides. The boom arms were approximately 2 m (6.5 ft) in length and pivoted 180 degrees, allowing the anodes to suspend directly in front of the bow. The boat's hull acted as the cathode. Electrofisher controls were mounted on the center console and electrofisher output was controlled by footswitches on the work deck located on the bow. Also on the center console was a counter that logged, in seconds, electrofisher on-time. A 250–L (65–gallon) livewell was positioned in the center of the boat.

The electrofisher settings for current type, voltage range, amperage, pulses per second, and percent of selected pulse frequency were selected prior to sampling and adjusted occasionally during sampling, as needed, by the boat operator. Direct current and low voltage range (50 to 500 VDC) were used exclusively during this study. Current was maintained at 14 ± 1 amps. Pulse per second was set at 120 DC, with three exceptions when it was set at 60 DC. Percent of range varied between 20 and 45%. Total time spent electrofishing (shocking time) and total shocking distance were recorded for each location at the completion of sampling. Distance was calculated from waypoints taken with a handheld Global Positioning System (GPS) unit. Shocking time ranged from 1,023–6,166 seconds and distance ranged from 129–644 m (423–2,113 ft).

Electrofishing at the SWP Horseshoe Bend release site typically was timed to coincide with the scheduled release of fish regardless of the tidal stage, while Control Sites 1 and 2 were always sampled on the same day. Each site was sampled only once during each sampling period for a minimum number of five samplings per site. The SWP Curtis Landing release site was sampled six times: once in early September in an attempt to collect and tag additional predatory fish. The species composition data were used to interpret data collected during the Hydroacoustic and DIDSON surveys.

Sampling was constrained to a predetermined sampling area that included the littoral zone at each site. The area immediately surrounding the release pipe or pier structure (control sites) were also carefully sampled to ensure sufficient coverage. Upriver and downriver sampling boundaries were established at approximately 200 m (656 ft) on either side of the release pipe (release sites) or piling structure (control sites). A total of 400 m (1312 ft) was sampled at each site. No greater than 6–meter (20–ft) sections of the shoreline were sampled at any one time, due to the range of effectiveness of the electrofisher unit. Typically, each site was sampled beginning at the upriver or downriver boundary, depending on wind and current conditions. A GPS handheld receiver (iFinder Expedition C®, Lowrance, Tulsa, OK) was used to describe the site locations. GPS waypoints were recorded at the beginning and ending of sampling to ensure consistency in maintaining site boundaries. All waypoint coordinates were recorded in Universal Transverse Mercator (UTM) units.

Technicians applied current for approximately 10 seconds, followed by 2- to 5-second intervals of no shocking. This process was repeated several times per section depending on how quickly and how many fish surfaced. The technicians used nets with long fiberglass handles to scoop stunned fish from the water. Netted fish were deposited into the live-well for recovery. At the completion of sampling a location, all fish were identified to species and enumerated. The fork lengths (FL) in mm of up to twenty fish of each species were also measured. All fish, with the exception of adipose fin-clipped Chinook salmon and dead listed (endangered or threatened) species, were returned to the water. Adipose fin-clipped Chinook salmon were euthanized, bagged, and brought back to Stockton for coded wire tag (CWT) analysis by US Fish and Wildlife Service (USFWS). Dead listed species were brought back to Stockton and saved for future analysis.

Readings of water temperature, conductivity, dissolved oxygen, clarity, and depth along with wind speed, air temperature, tide, and time were recorded at the beginning and ending of each sampling session. Water temperature (°C), conductivity (µS/cm), and dissolved oxygen (% and mg/L) were measured using a multi-probe meter (YSI Models MPS 556 and 85, YSI Incorporated, Yellow Springs, OH). Water clarity was measured in centimeters using a Secchi disc.

Water depth was recorded in meters from the depth logger on the boat. Wind speed in kilometers per hour was obtained from posted data on http://cdec.water.ca.gov and air temperature (°C) was obtained from posted data on www.wunderground.com. Tidal conditions were observed in the field and confirmed from posted data at www.saltwatertides.com.

2.1.2 Floy Tags and Telemetry

To examine predatory fish movement and behavior at release sites, Floy tags (mark and recapture) were employed to obtain information on predator site fidelity for predatory fish collected during electrofishing, including largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus)*, striped bass (*Morone saxatilis*), and Sacramento pikeminnow (*Ptychocheilus grandis)*. Largemouth bass and black crappie were Floy tagged. Striped bass and Sacramento pikeminnow not used for the acoustic tag study were also Floy tagged. Each Floy tag was applied to the fish on the left-dorsal area using the Avery Dennison Mark II™ pistol L. Tagging was performed in such a way as to minimize stress to the fish. Fish tagging was discontinued if a fish was not tagged after two attempts. Each Floy tag had a unique identification number and a phone number for DWR. Predatory fish that were recaptured during electrofishing were measured and weighed; the tag number was recorded and the fish was released.

Acoustic telemetry data was used to determine if the tagged fish remained at the release site, were attracted to the release site during a fish release, moved to another location (for example, a control site or other release site), or moved seasonally to and from the release site. Sacramento pikeminnow and striped bass collected during electrofishing were fitted with acoustic transmitters. These two species were selected based on their larger size, habitat preferences, and occurrence in previous field studies (Orsi 1967, Pickard and others 1982). Largemouth bass were not selected for acoustic telemetry tracking because they sometimes remain in a restricted area (Moyle 2002) and the detections from such individuals could have quickly filled the receiver's data storage capacity. Most black crappie were not large enough for use with the smallest acoustic tags purchased for this study, and were too small for Floy tags per the minimum length requirement (predatory fish ≥ 150 mm [5.9 in] FL) (DWR 2005). Most striped bass and Sacramento pikeminnow greater than approximately 400 mm [15.7 in] FL (weighing 450 g [1 lb] or more) caught during electrofishing were fitted with acoustic transmitters. Only fish in good condition with no sores, hemorrhages, or badly frayed fins were selected for acoustic tagging. Movement of acoustically tagged fish was continuously monitored throughout the study using an array of fixed receivers deployed in and around the receiving waters of the release sites. Additionally, fish movement was periodically monitored using a mobile receiver and a hydrophone.

Acoustic telemetry products made by VEMCO, a division of AMIRIX Systems, Inc. (Halifax, Nova Scotia), were used exclusively during this study. Refer to

Appendix 11.1 for information on VEMCO technology, tag, and receiver information. All tags used were less than 2% of the weight of the fish (largest tag weighed 6 g [0.013 lb] and the lightest fish weighed 454 g [1 lb]). The use of an appropriate-sized transmitter ensured minimal impact on swimming performance (Winter 1983 and 1996). The largest tags (Vemco V13-1L) used in the study had an estimated life of 325 days, while the smallest tags (Vemco V9-1L) had an estimated life of 115 days.

The transmitters were designed for surgical implantation. Therefore, each tag had to be modified for external mounting. A 25–cm (10–in) piece of galvanized-steel wire (0.41 mm diameter or 28-gauge) was affixed to the transmitter using polyolefin heat shrink tubing. Two pieces of shrink tubing were cut slightly smaller than the length of the transmitter. One piece was placed over the transmitter and the wire was placed between the shrink tubing and the transmitter. A Ronson® butane lighter (Somerset, NJ) was used to heat the shrink tubing. As the tubing warmed, it shrank around the transmitter, securing the wire to the transmitter. The second piece of shrink tubing was applied in the same fashion for reinforcement.

Each fish, before receiving a transmitter, was measured and weighed (BogaGrip® Model 130, Eastaboga Tackle, Eastaboga, AL) and the appropriate transmitter number was recorded. Securing the transmitter to the fish was performed in a similar manner to the method described by Chadwick (1963), Gray and Haynes (1979), and Gingras and McGee (1997). Hypodermic needles were pushed through the fish below the dorsal fin, starting on the left side of the fish. Through the needle openings, now on the right side of the fish, the wire from the transmitter was threaded. The needles were quickly pulled from the fish, thus pulling the wire through the body of the fish. The two ends of the wire were pulled tightly, twisted several times, cut, and the excess pushed against the fish towards the posterior. During the tagging process, the fish was secured in a cradle and water was pumped across its gills. Once tagging was complete, the fish was released to the water and its condition noted.

VEMCO VR2 receivers were deployed at seven separate locations in the study area (Figure 11 and Table 2). The receivers were situated as close as possible to the release pipe or piling structure at all four release sites and the two control sites. Two additional receivers were deployed in December 2006 as part of another study: in Horseshoe Bend at Decker Island (DI) and in the Sacramento River at Sherman Island (SAC). The same mooring method was used to secure all receivers. Each receiver was secured to the middle section of a 3-meter (10 ft) long piece of nylon rope using zip-ties (36.83 cm length x 0.76 cm width [14.5 in x 0.3 in]). Zip-ties were fastened in accordance with the VEMCO VR2 Receiver Operating Manual (VEMCO 2004). A float was tied to the end of the rope above the receiver's transducer. A 5–kg (11–lb) weight was tied to the other end of the rope. This setup allowed the receiver to orient nearly vertically in the water column, with the transducer pointed towards the surface.

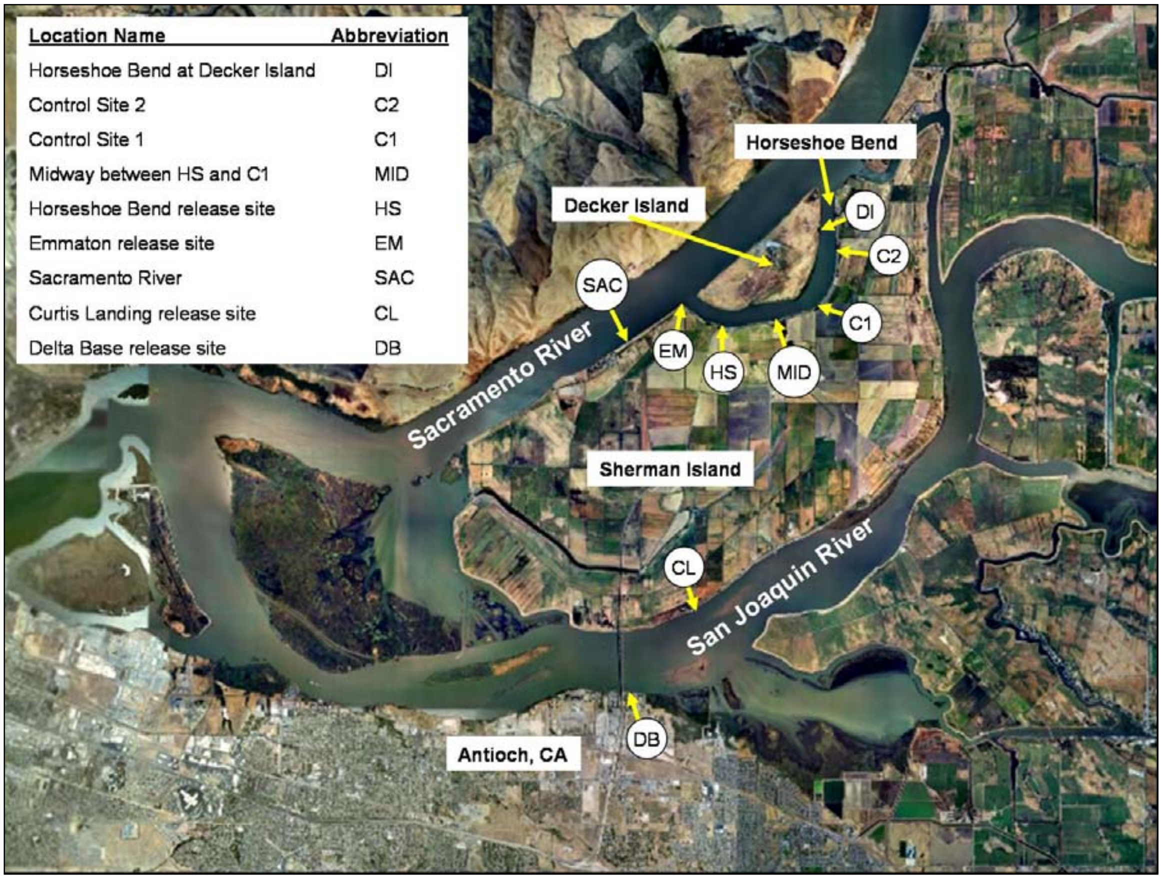


Figure 11- VR2 receiver deployment locations

At all locations, except midway between Control Site 1 and the SWP Horseshoe Bend release site, a first-generation VR2 receiver was deployed along with a second-generation unit. These redundant receivers provided a backup in case of malfunction, damage, or loss of either receiver. The older units were fastened to the line in the same manner as the new units. The data from the newer receivers was used for data analysis purposes since they generally recorded more tag detections than the older units. Based on some range testing using similar tags, 100% tag detection was observed at a maximum range of 160 m (525 ft). Actual detection ranges were expected to vary with depth, channel profile, submerged vegetation, and surface conditions.

Table 2- VR2 receiver deployment locations with GPS waypoints

Location Name	Location Abbreviation	Date Deployed	Time Deployed	Receiver Serial Number	Easting (UTM)	Northing (UTM)	Approximate depth (m)
Control Site 1	C1	06/27/07	0806	6324C	613008	4215897	10.6
		07/11/07	0847	3185C			
Control Site 2	C2	06/27/07	0849	6342C	613381	4216929	4
		07/11/07	0907	3174C			
SWP Horseshoe Bend release site	HS	07/02/07	1015	6320C	611374	4215554	4
		07/05/07	1235	3201C			
CVP Emmaton release site	EM	07/02/07	1058	6335C	610813	4215878	15.2
		07/09/07	0822	3183C			
SWP Curtis Landing release site	CL	07/02/07	1223	6336C	610876	4210182	9.4
		07/10/07	1143	3186C			
CVP Delta Base release site	DB	07/16/07	0828	6309C	609699	4208756	3.3
		07/16/07	0828	3187C			
Midway between HS and C1	MID	07/23/07	1100	6345C	612169	4215653	9.7
		10/11/07	1140	6345C	612122	4215625	7.3

Relocated MID receiver on October 11, 2007; original position too accessible from shoreline
Lost 3183C on a snag and replaced with 6317C on March 7, 2008

Detection data from the receivers was downloaded about once every three weeks. This process required removing the receiver from the water for a short time. The VEMCO VR-PC computer interface was used to download data from the receiver to a laptop. VEMCO VR2 Windows Software, version 1.0.21.0, was used to download data files to the computer. A backup copy of each file was created on a flash drive for precautionary purposes. While downloading, the mooring cable and line, zip-ties, weight, float, and the receiver were inspected for wear. Items were replaced or mended, if necessary. When the downloading process was completed and after the receiver had been initialized, the receiver was checked for proper performance. A “test” transmitter was placed next to the receiver’s hydrophone. The receiver was deemed functional and returned to the water upon a positive detection of the “test” transmitter. Downloading all receivers for all locations was accomplished in one to two days, depending on the weather and the amount of data on each receiver.

In addition to the fixed receivers, remote tracking, or mobile monitoring (MM), was performed one or two times per month using a VEMCO VR100 acoustic tracking receiver. Three locations within Horseshoe Bend were chosen for mobile monitoring (Figure 12). All three locations were accessed from a boat. At each location, an omni-directional hydrophone (VEMCO model VH165) was lowered into the water. The VR100 was programmed with the code map and frequency appropriate for transmitters used for this study. If a transmitter was present in the area, the transmitter code, signal strength, and time of detection were displayed on the screen of the VR100. This information was recorded only once for each transmitter. After approximately 5 minutes, if no additional transmitters were detected, the hydrophone was pulled from the water and the next location was monitored.

Mobile monitoring was used primarily to check for “dead zones”, areas of no detection, within the array of receivers in Horseshoe Bend. When compared to the fixed receiver data, no dead areas were observed during the mobile monitoring and the results validated the detection areas of the fixed receivers. Based on these results, mobile monitoring data was not used in the telemetry data analysis.

VEMCO User Environment (VUE) software (version 1.2.1) was used to maintain and analyze all VR2 receiver data. Downloaded receiver files stored on the laptop were copied to a desktop computer for analysis with the VUE software. Each receiver file was imported into VUE and was assigned a location based upon the location of the receiver in the field.

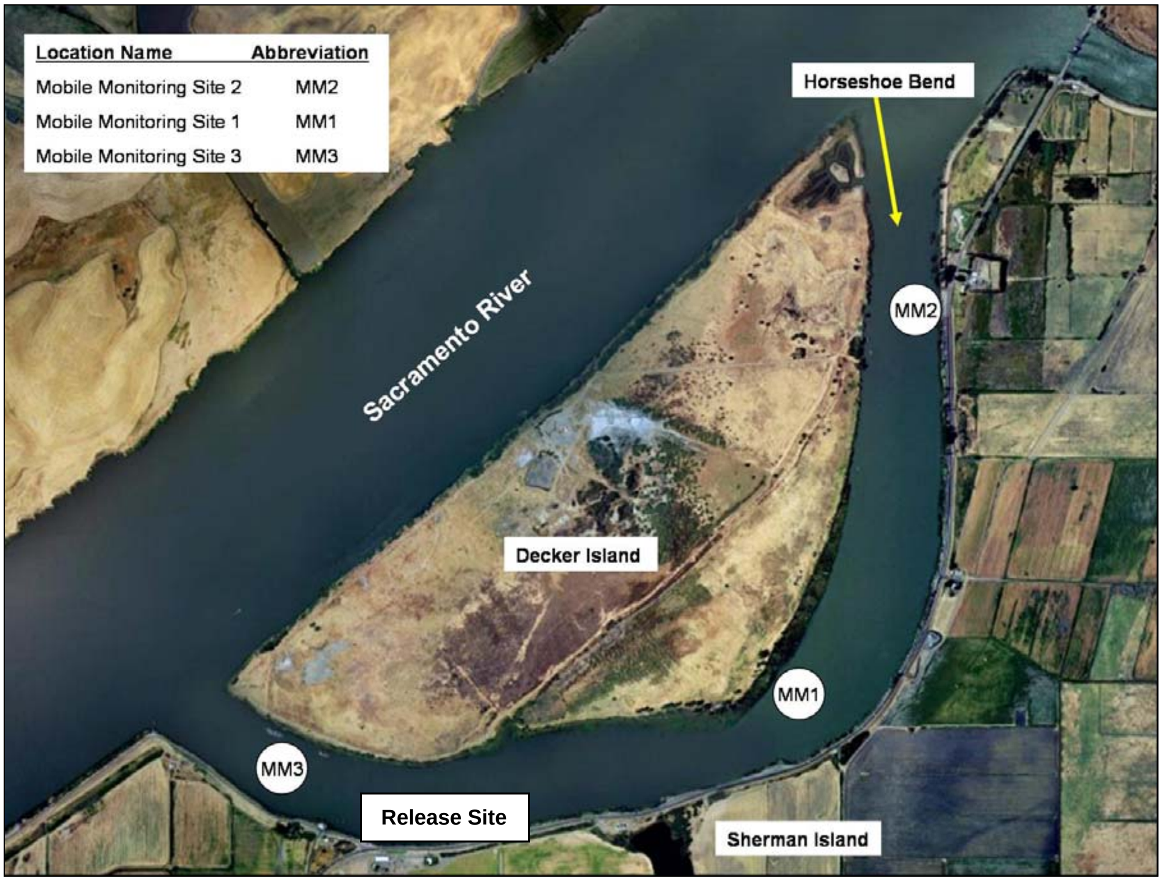


Figure 12 -Map showing location of mobile monitoring locations

From VUE, data for each tag used in this study was exported to Microsoft Excel (Redmond, WA). Data in Excel was imported into Microsoft Access (Redmond, WA). A table was created in Access with the following fields: receiver serial number, tag number, detection date, and detection time. This table contained only the tags used and detected for this study. Additionally, telemetry detections from the California Fish Tracking Consortium (Consortium) database were added to this table (http://californiafishtracking.ucdavis.edu). The Consortium is a collaboration of researchers from several academic, government, and private organizations working together to better understand the life histories of anadromous fish species of California. The Consortium uses a large array of underwater acoustic receivers to monitor the movement of acoustically-tagged fish which ranges from the Sacramento River below Lake Shasta down to the Golden Gate Bridge in San Francisco Bay. Queries summarized data for (1) number of detections of each tag number per receiver by hour and (2) number of detections of each tag number per receiver by day. The location of the receiver with the greatest detections per hour for a specific tag (fish) was deemed to be the location for that fish during that time period. Hourly detections of ≤ 2 per receiver were considered false detections. False detections were not considered when assigning tag (fish) location.

Hourly detection data filtered from the Access database were copied into individual Excel spreadsheets by fish (tag number). Each spreadsheet contained column headings showing the location and serial number of each VR2 receiver that detected the specific tag number. The columns were arranged (left to right) according to increasing distance (river miles) away from the Horseshoe Bend study area. The rows contained the tag number, fish species, detection date, and detection time from the first detection to the last detection. Setting up the spreadsheet in this manner allowed for examining the pattern of detections for logical signs of reasonable fish movement. This design also allowed for excluding simultaneous valid detections from receivers more than a mile apart whose pattern of detections was not a logical sign of reasonable fish movement.

2.1.3 Telemetry Data Analysis

The telemetry detection data was summarized based on the percentage of days monitored that fish resided at a salvage release site using the formula:

% Time at Release Site= (# Days detected at a Release Site / # Days Monitored) X 100.

A Mann-Whitney Rank Sum Test was used to compare the percentage of time spent at a release site for Sacramento pikeminnow and Striped Bass.

2.2 Quality Assurance

Regularly scheduled maintenance was performed, per operations manual, on the YSI 556 multi-probe meter and the YSI 85. Each field-day, the YSI 556 and 85 were calibrated for dissolved oxygen (mg/L and %). The YSI 556 was calibrated using barometric pressure value (mm Hg). Barometric pressure (in millibars) was obtained from the handheld GPS unit and converted to mm Hg by multiplying by the constant, 0.750064. The YSI 85 was calibrated using local altitude in hundreds of feet. Local altitude was considered to be zero in the area of fieldwork during this study. No attempt was made to determine the accuracy of Secchi disc or water depth.

All field personnel received training in proper fish identification. Additionally, the field lead biologist reminded staff of key characteristics for which to check when identifying fish to species. No attempt was made to determine the accuracy of the measuring boards or BogaGrip® used to measure the length and weight of fish, respectively.

The field lead checked all datasheets for completeness at the end of each day. The field lead entered all field data into a Microsoft Access database. Scientific aides checked entries line-by-line (printed copy of data) against the field datasheets. Aides circled any errors on the printout; the field lead corrected the errors in the database.

2.3 Results

2.3.1 All Species

Twenty-six different fish species were collected during electrofishing (Table 3), including eight native species and 18 introduced species. This ratio of native to introduced species is consistent with other studies in the region which have shown that macrophyte dominated shorelines, such as those sampled during this study, are primarily inhabited by introduced species adapted to these littoral habitats (Feyrer and Healy 2003, Grimaldo and others 2004, Nobriga and others 2005). Species composition was most diverse at Control Site 2; this location exhibited 23 of the 26 species collected during this study (Table 3). Eighteen fish species were collected at Control Site 1. Seventeen fish species were collected each at the SWP Curtis Landing and Horseshoe Bend release sites.

The most abundant species was redear sunfish (*Lepomis microlophus*), followed by tule perch (*Hysterocarpus traskii*) and largemouth bass. These three species were collected at all sampling locations throughout the entire sampling period (Table 4). Bluegill (*L. macrochirus*), golden shiner (*Notemigonus crysoleucas*), and inland silverside *(Menidia beryllina*) were also collected frequently. Least abundant were the following 6 species: brown bullhead (*Ameiurus nebulosus*), goldfish (*Carassius auratus*), red shiner (*Cyprinella lutrensis*), smallmouth bass (*M. dolomieu*), steelhead (*O. mykiss*), and yellowfin goby (*Acanthogobius flavimanus*). These 6 species were only collected once during the entire study.

The total number of fish collected for the entire study was 3,100. The total number of fish collected at the SWP Horseshoe Bend and Curtis Landing release sites and Control Site 2 were comparable (Table 3). For Control Site 1, the total number of fish collected was noticeably lower than the other three sampling sites. The most common species by location was: Control Site 1 = largemouth bass; Control Site 2 = redear sunfish; SWP Curtis Landing release site = tule perch; and SWP Horseshoe Bend release site = redear sunfish (Table 3).

2.3.2 Predatory Species

We collected 10 species of predatory (piscivorous) fish. Largemouth bass, bluegill, black crappie, Sacramento pikeminnow, and striped bass were the top five predatory species, in order of highest to lowest abundance. Length and weight ranges and averages were calculated for each predatory species (Table 5).

At all locations, centrarchids were caught primarily near shore, in tules and woody (root) areas. Based on field observations, none of the centrarchids or ictalurids were collected while sampling (electrofishing) at or near (within about 3 m [10 ft]) of the end of the SWP release pipes at Horseshoe Bend or Curtis Landing. Striped bass and large (>390 mm [15.3 in] FL) Sacramento pikeminnow typically were caught when sampling at or near (within 5 m [15 ft]) the end of the SWP Horseshoe Bend release pipe. Pikeminnow collected at the control sites were typically caught near shore, sometimes near piling structures.

Pikeminnow collected at SWP Curtis Landing were collected near shore in the tules. Striped bass collected at the control sites were less than 200 mm (7.9 in) FL, with the exception of one fish (551 mm [21.7 in] FL) collected at Control Site 1. Striped bass collected at the SWP Horseshoe Bend release site were greater than 400 mm (15.7 in) FL.

Collection numbers varied among the top five predators. Largemouth bass were collected fairly consistently at all sampling locations for the entire study period. No fewer than 10 and no greater than 63 were collected at any one time, at any location (Table 4). On some sampling days no bluegill, black crappie, or Sacramento pikeminnow were collected (Table 4).

Twenty-two striped bass were collected in the sampling. Of these, 15 were collected at the SWP Horseshoe Bend release site, and only during August and October 2007 (Table 4). No striped bass were collected at the SWP Horseshoe Bend release site from December 2007 through March 2008. Four of the 22 striped bass were collected at Control Site 1 during October 2007 and March 2008. Only one striped bass collected at Control site 1 in March 2008 was greater than 200 mm (7.8 in) FL (Table 6). Three of the 22 striped bass were collected at Control Site 2, and only during the March 2008 sampling period. None was greater than 175 mm (6.9 in) FL (Table 6). No striped bass were collected at the SWP Curtis Landing release site (Table 6).

Table 3- Species collected while electrofishing. C1=Control 1, C2=Control 2, CL=SWP Curtis Landing release site, and HSB= SWP Horseshoe Bend release site

Common Name	Scientific Name	Catch by sampling location				Total
		C1	C2	CL	HSB	
Black crappie	*Pomoxis nigromaculatus*	1	20	14	38	73
Bluegill	*Lepomis macrochirus*	10	47	46	92	195
Brown bullhead	*Ameiurus nebulosus*		1			1
Carp	*Cyprinus carpio*	9	6	2	2	19
Chinook salmon*	*Oncorhynchus tshawytscha*	2	9		2	13
Delta smelt*	*Hypomesus transpacificus*		2			2
Golden shiner	*Notemigonus crysoleucas*	11	54	47	32	144
Goldfish	*Carassius auratus*			1		1
Hitch*	*Lavinia exilicauda*	6	29	26	17	78
Inland silverside	*Menidia beryllina*	37	64	6	37	144
Largemouth bass	*Micropterus salmoides*	92	202	120	153	567
Red shiner	*Cyprinella lutrensis*		1			1
Redear sunfish	*Lepomis microlophus*	62	300	190	318	870
Sacramento blackfish*	*Orthodon microlepidotus*	1	25	1	42	69
Sacramento pikeminnow*	*Ptychocheilus grandis*	15	16	11	29	71
Sacramento sucker*	*Catostomus occidentalis*	26	8	3	4	41
Shimofuri goby	*Tridentiger bifasciatus*		2			2
Smallmouth bass	*Micropterus dolomieu*		1			1
Spotted bass	*Micropterus punctulatus*	3	3	1	1	8
Steelhead*	*Oncorhynchus mykiss*			1		1
Striped bass	*Morone saxatilis*	4	3		15	22
Threadfin shad	*Dorosoma petenense*	6	1		7	14
Tule perch*	*Hysterocarpus traskii*	36	117	401	192	746
Warmouth	*Lepomis gulosus*		3	4	3	10
White catfish	*Ameiurus catus*	1	2	3		6
Yellowfin goby	*Acanthogobius flavimanus*	1				1
	Sum of Catch =	**323**	**916**	**877**	**984**	**3,100**
	Count of Species =	**18**	**23**	**17**	**17**	**26**

*Native species

Table 4- Species collected by sampling date and sampling location

Sampling date	Sampling location	Black crappie	Bluegill	Brown bullhead	Carp	Chinook salmon	Delta smelt	Golden shiner	Goldfish	Hitch	Inland silverside	Largemouth bass	Red shiner	Redear sunfish	Sacramento blackfish	Sacramento pikeminnow	Sacramento sucker	Shimofuri goby	Smallmouth bass	Spotted bass	Steelhead	Striped bass	Threadfin shad	Tule perch	Warmouth	White catfish	Yellowfin goby
08/23/07	HS	2	9		1							20		5	33	11	4			1		8		10			
08/24/07	C1	1			2					3		10		2	1		8							7			
08/24/07	C2	3	4		2							22	1	4	8	3	5		1					9		2	
08/28/07	CL	1	2					3		2		18		7	1	3								14			
09/05/07	CL	1	3		1			5		5		13		11		2				1				17	1	1	
10/25/07	C1		6					1			1	17		21		1	7			3		3	6	5		1	1
10/25/07	C2	5	6		1			10		3	52	43		25	6	1	1			3			1	27			
10/26/07	HS	2						1			15	11		4	2	11						7	7	5			
10/29/07	CL	1						1		1		17		8										16		2	
12/13/07	C1		2					8		3	36	16		17		5	10							9			
12/13/07	C2	1	6	1				5			12	15		61	2		1							13			
12/14/07	HS	12	22					2		3	21	39		100	4	2								38			
12/21/07	CL		1								1	11		4		3	3							2			
02/19/08	CL	8	28		1			34	1	11	4	35		128		2					1			332	3		
02/20/08	HS	17	36			1		22		10	1	63		169	3	4								126	1		
02/26/08	C1		1			2		2				23		9		8								13			
02/26/08	C2	8	11			9		29		15		63		138	5	5		1						34	3		
03/26/08	C1		1		7							26		13		1	1					1		2			
03/26/08	C2	3	20		3		2	10		11		59		72	4	7	1	1				3		34			
03/27/08	CL	3	12					4		7	1	26		32		1								20			
03/28/08	HS	5	25		1	1		7		4		20		40		1								13	2		
	Total =	**73**	**195**	**1**	**19**	**13**	**2**	**144**	**1**	**78**	**144**	**567**	**1**	**870**	**69**	**71**	**41**	**2**	**1**	**8**	**1**	**22**	**14**	**746**	**10**	**6**	**1**

Table 5- Fork length (mm) and weight (kg) of piscivorous fish collected. Number measured and number weighed denoted by "N"

Species	Fork Length (mm)				Weight (kg)			
	N	Min	Max	Avg	N	Min	Max	Avg
Largemouth bass	419	41	550	237	96	0.45	4.31	1.11
Bluegill	160	22	240	115	0	N/A	N/A	N/A
Black crappie	73	45	260	106	0	N/A	N/A	N/A
Sacramento pikeminnow	71	61	651	362	34	0.23	3.86	1.99
Striped bass	22	119	711	406	11	1.13	4.54	2.10
Warmouth	10	46	160	122	0	N/A	N/A	N/A
Spotted bass	8	68	356	135	0	N/A	N/A	N/A
White catfish	6	237	372	293	0	N/A	N/A	N/A
Brown bullhead	1	230	230	230	0	N/A	N/A	N/A
Smallmouth bass	1	143	143	143	0	N/A	N/A	N/A

Table 6- Striped bass collected per sampling date and sampling location

Sampling date	Sampling location	Number collected	Min FL (mm)	Max FL (mm)
08/23/07	HS	8	416	711
10/25/07	C1	3	166	193
10/26/07	HS	7	406	636
03/26/08	C1	1	551	551
03/26/08	C2	3	119	174

2.3.3 Catch per Unit Effort

Catch per unit effort (CPUE) was calculated for time (per hour of applied current) and distance (per meter of shoreline shocked); (Table 7). CPUE was calculated using total catch of all species per sampling date per sampling location. Catch per hour and per meter fished were highest at the SWP Curtis Landing release site on February 19, 2008. We collected 588 fish in 4,522 shocking seconds or 400 m (1,312 ft), which equated to 468 fish for every hour of electrofishing or 1.461 fish for every meter (0.44 fish/ft) Catch per hour and per meter were lowest at the SWP Curtis Landing release site on December 21, 2007. Twenty-five fish were collected in 2,271 shocking seconds or 400 m (1,312 ft), which equated to 40 fish for every hour of electrofishing or 0.062 fish for every meter (0.019 fish/ft) of shoreline. The highest and lowest CPUE values coincided with the near-lowest and highest average river conductivity values, respectively (Table 7).

Table 7- Catch per unit effort by sampling date and sampling location. River conductivity is average of start and end sampling values

Sampling date	Sampling location	Total catch	Catch per hour	Catch per meter	Conductivity (µS/cm)
08/23/07	HS	104	357	0.130*	456
08/24/07	C1	34	113	0.085	1,442
08/24/07	C2	64	211	0.159	1,339
08/28/07	CL	51	179	0.106	1,630
09/05/07	CL	61	178	0.095	1,577
10/25/07	C1	73	165	0.174	406
10/25/07	C2	184	408	0.440	654
10/26/07	HS	65	174	0.238	1,403
10/29/07	CL	46	87	0.114	2,271
12/13/07	C1	106	165	0.263	423
12/13/07	C2	117	183	0.291	450
12/14/07	HS	243	208	0.604	1,444
12/21/07	CL	25	40	0.062	3,033
02/19/08	CL	588	468	1.461	206
02/20/08	HS	453	264	1.126	203
02/26/08	C1	58	89	0.144	191
02/26/08	C2	321	392	0.798	197
03/26/08	C1	52	86	0.129	220
03/26/08	C2	230	290	0.572	214
03/27/08	CL	106	166	0.263	259
03/28/08	HS	119	243	0.924	235

*Electrofishing distance was not recorded, estimated at 800 m

Catch per hour and per meter were also calculated for three predatory species: largemouth bass, Sacramento pikeminnow, and striped bass (Table 8). Catch per hour and catch per meter were always greatest for largemouth bass at all four sites sampled. CPUE was generally lower for Sacramento pikeminnow with fewer caught at all sites, and in general few striped bass were captured (none were caught at the SWP Curtis Landing release site). At the SWP Horseshoe Bend release site, CPUE for Sacramento pikeminnow and striped bass was generally highest during the summer and spring monitoring periods then gradually decreased as the study progressed. In contrast, CPUE for largemouth bass was highest during the summer monitoring period then lower and relatively constant for the rest of the study.

Table 8 - Catch per unit effort by sampling date and location of three predatory fishes: Largemouth bass, Sacramento pikeminnow, and striped bass. Missing values indicate no catch.

		Largemouth bass			Sacramento pikeminnow			Striped bass		
Sampling date	**Sampling location**	**Total catch**	**Catch per hour**	**Catch per meter**	**Total catch**	**Catch per hour**	**Catch per meter**	**Total catch**	**Catch per hour**	**Catch per meter**
08/23/07	HS	20	69	0.025*	11	38	0.014*	8	27	0.010*
08/24/07	C1	10	33	0.025						
08/24/07	C2	22	73	0.055	3	10	0.007			
08/28/07	CL	18	63	0.037	3	11	0.006			
09/05/07	CL	13	38	0.020	2	6	0.003			
10/25/07	C1	17	38	0.041	1	2	0.002	3	7	0.007
10/25/07	C2	43	95	0.103	1	2	0.002			
10/26/07	HS	11	29	0.040	11	29	0.040	7	19	0.026
10/29/07	CL	17	32	0.042						
12/13/07	C1	16	25	0.040	5	8	0.012			
12/13/07	C2	15	24	0.037						
12/14/07	HS	39	33	0.097	2	2	0.005			
12/21/07	CL	11	17	0.027	3	5	0.007			
02/19/08	CL	35	28	0.087	2	2	0.005			
02/20/08	HS	63	37	0.157	4	2	0.010			
02/26/08	C1	23	35	0.057	8	12	0.020			
02/26/08	C2	63	77	0.157	5	6	0.012			
03/26/08	C1	26	43	0.065	1	2	0.002	1	2	0.002
03/26/08	C2	59	74	0.147	7	9	0.017	3	4	0.007
03/27/08	CL	26	41	0.065	1	2	0.002			
03/28/08	HS	20	41	0.155	1	2	0.008			

*Electrofishing distance was not recorded, estimated at 800 m

2.3.4 Acoustic and Floy Tagged Predators

Twenty-eight predators (7 striped bass and 21 Sacramento pikeminnow) were fitted with acoustic tags (Table 9). Only legal-sized (greater than or equal to 457 mm [18 in] total length or 420 mm [16.5 in] FL) striped bass were fitted with acoustic tags. Only adult Sacramento pikeminnow were tagged.

Table 9- Fork length (mm) and weight (kg) of tagged predators

Tag Method	Species	Fork Length (mm)				Weight (kg)			
		N	Min	Max	Avg	N	Min	Max	Avg
Acoustic Tag	Striped bass	7	465	711	554	7	1.36	4.54	2.49
	Sacramento pikeminnow	21	397	645	534	21	0.45	3.63	2.05
Floy Tag	Largemouth bass	76	215	550	363	57	0.45	4.31	1.27
	Sacramento pikeminnow	15	249	651	490	10	0.23	3.86	1.77
	Striped bass	6	406	525	461	4	1.13	1.81	1.42
	Black crappie	1	260	260	260	0	N/A	N/A	N/A

Ninety-eight predators were tagged with Floy tags (Table 9). No fish were Floy tagged in March 2008 as this was the final sampling event and there was no possibility of recapture by electrofishing. Largemouth bass were Floy tagged during each sampling effort. At least one Sacramento pikeminnow was Floy tagged during each sampling period. Six were tagged at the SWP Horseshoe Bend release site on October 26, 2007 after eight fish had already been fitted with acoustic tags. Striped bass were Floy tagged only at the SWP Horseshoe Bend release site. One black crappie was Floy tagged at the SWP Horseshoe Bend release site.

2.3.5 Recaptured Fish

Eight of the 98 Floy tagged predators were recaptured in subsequent sampling periods. Seven of these recaptured fish were largemouth bass; the other was a Sacramento pikeminnow (Table 10). All fish were recaptured at the location at which they were tagged/released and were only recaptured once. The longest time between tagging and subsequent recapture was for a Sacramento pikeminnow tagged/released in the August 2007 sampling period and recaptured four months later in the December 2007 sampling period.

Table 10- Recapture information of floy-tagged predators

Species	Floy tag Number	Tagged or Recaptured	Date	Location	Fork Length (mm)	Weight (kg)
Largemouth bass	024	Tagged	10/25/07	C2	378	1.13
Largemouth bass	024	Recaptured	03/26/08	C2	390	0.91
Largemouth bass	105	Tagged	12/13/07	C1	336	1.13
Largemouth bass	105	Recaptured	03/26/08	C1	348	0.68
Largemouth bass	116	Tagged	12/14/07	HS	388	0.91
Largemouth bass	116	Recaptured	02/20/08	HS	389	1.13
Largemouth bass	145	Tagged	02/26/08	C2	350	0.91
Largemouth bass	145	Recaptured	03/26/08	C2	361	0.91
Largemouth bass	153	Tagged	02/26/08	C2	396	0.91
Largemouth bass	153	Recaptured	03/26/08	C2	no data	no data
Largemouth bass	157	Tagged	02/26/08	C1	386	1.13
Largemouth bass	157	Recaptured	03/26/08	C1	390	1.13
Largemouth bass	468	Tagged	08/28/07	CL	314	no data
Largemouth bass	468	Recaptured	09/05/07	CL	327	no data
Sacramento pikeminnow	494	Tagged	08/23/07	HS	621	no data
Sacramento pikeminnow	494	Recaptured	12/14/07	HS	630	3.63

2.3.6 Environmental Parameters

Environmental parameters (water and air temperature, river conductivity, dissolved oxygen, Secchi disk depth, and wind speed) were measured at each sampling (electrofishing and mobile monitoring); (Table 11). Parameter values were recorded at the start and end of each electrofishing sample location. During mobile monitoring, parameters were recorded only once, upon arrival at the location. The time at which parameters were taken was recorded. Dissolved oxygen (% saturation) was not recorded during the August 2007 electrofishing period. Additionally, parameters were recorded only for the start of sampling for electrofishing performed on August 23, 24, and 28, 2007. GPS coordinates were not recorded for mobile monitoring performed on January 17, 2008 due to instrument malfunction. Depth values were not consistently recorded during mobile monitoring surveys. Only river conductivity data and water temperature data were used for analysis of fish movement.

Water temperatures changed expectedly between sampling periods (seasons); the lowest and highest temperature values were recorded in December 2007 and August 2007, respectively (Figure 13). Dissolved oxygen (both % and mg/L) levels remained fairly constant throughout the study period, never dropping below 7.50 mg/L or 80.2% saturation. Water clarity, measured as Secchi disk depth, trended downward during the study period, though values were highly variable during October 2007 and December 2007. Wind speeds were also highly variable throughout the study. Air temperature trended downward from the first sampling period to the last; the coldest temperatures were recorded during the December 2007. Tidal fluctuations were compared with river conductivity values. Higher conductivity readings were not always associated with a high slack or flood tide. Some conductivity values were less than 500 μS/cm during a high slack or flood tide. In general, river conductivity was variable, but highest during the late-fall and winter (Figure 14).

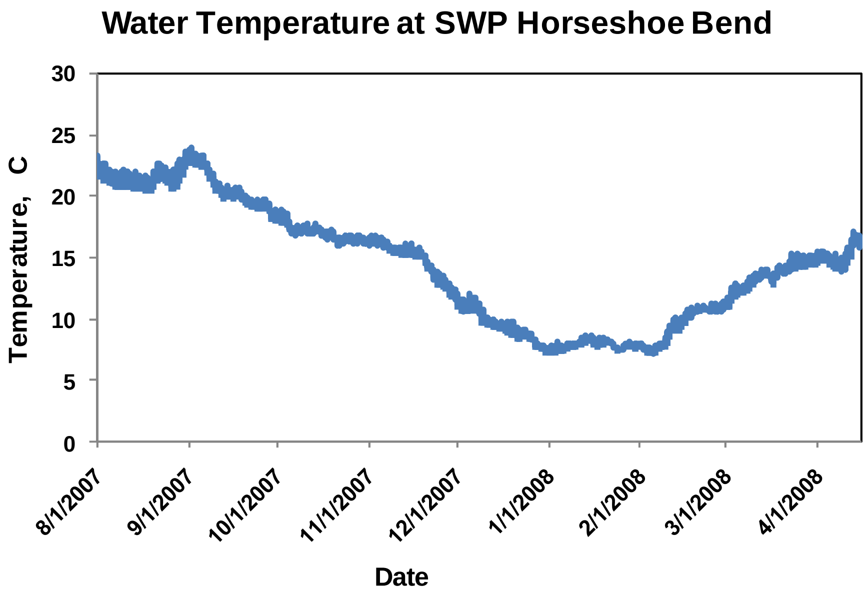


Figure 13-Water temperature at the SWP Horseshoe Bend release site for the duration of the study period.

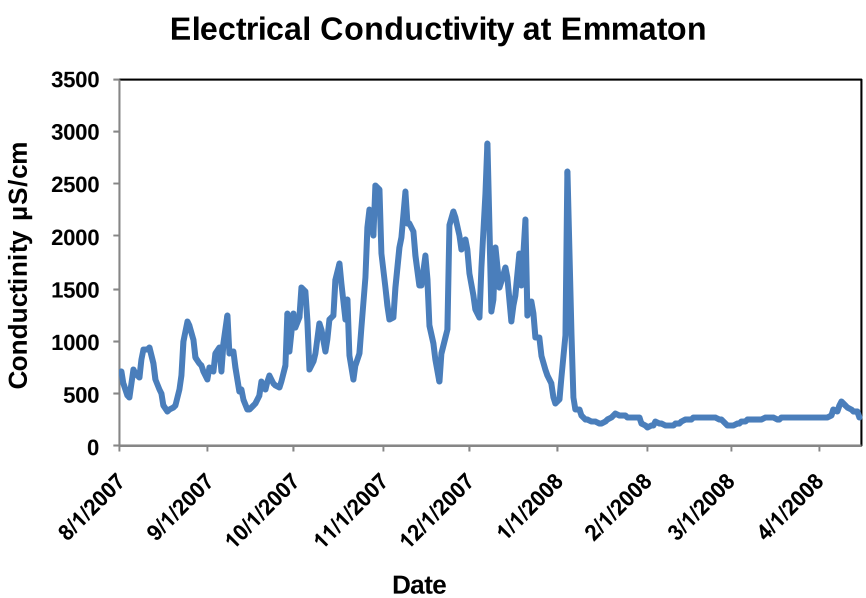


Figure 14-Electrical conductivity at Emmaton during the study period.

Table 11- Environmental parameters values for: (A) electrofishing and mobile monitoring data combined, (B) electrofishing data only, and (C) mobile monitoring data only

A	Water Temperature (°C)	Conductivity (μS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Secchi Disc (cm)	Depth (m)	Wind Speed (km/h)	Air Temperature (°C)
Average	13.87	725	94.85	9.79	59	4	12	16.76
Minimum	7.64	132	80.20	7.50	14	1	3	-0.60
Maximum	23.10	3,725	106.60	12.43	110	14	31	33.70
N	63	63	53	63	63	58	46	46

B	Water Temperature (°C)	Conductivity (μS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Secchi Disc (cm)	Depth (m)	Wind Speed (km/h)	Air Temperature (°C)
Average	14.36	832	95.05	9.69	64	5	11	16.69
Minimum	9.36	190	83.10	7.50	31	2	3	-0.60
Maximum	23.10	3,470	106.60	11.90	110	14	31	33.70
N	38	38	32	38	38	38	42	42

C	Water Temperature (°C)	Conductivity (μS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Secchi Disc (cm)	Depth (m)	Wind Speed (km/h)	Air Temperature (°C)
Average	13.12	563	94.55	9.94	51	4	24	17.50
Minimum	7.64	132	80.20	7.93	14	1	18	15.50
Maximum	20.70	3,725	105.80	12.43	73	8	29	20.10
N	25	25	21	25	25	20	4	4

2.3.7 Fish Telemetry

Twenty-eight predators were tagged with acoustic transmitters between August 23, 2007, and March 26, 2008 (Table 12), comprised of 21 adult Sacramento pikeminnow and seven adult striped bass. Adult striped bass with acoustic transmitters from the SWP Horseshoe Bend release site were generally detected moving away from the vicinity of the release site (Table 13). Only one tagged striped bass remained exclusively at the initial tagging location. However, this fish's tag was detected for a period of only two days after tagging (Table 12). This particular fish may have been caught and removed by an angler or the acoustic tag may have failed. One striped bass was tagged at the SWP Horseshoe Bend release site in October 2007 and was detected at both SWP release sites as well as at both CVP release sites. Between August 2007 and April 2008, acoustic-tagged striped bass were detected on the array of Consortium receivers as far north and east as Snodgrass Slough (Sacramento Co.), as far south as Antioch (Contra Costa Co.), and as far west as Mare Island (Solano Co.; Figure 15). One tagged striped bass was detected moving back and forth twice between the Sacramento River just downstream of Decker Island and the Carquinez Bridge between November 2007 and February 2008. Figure 16 shows the movement of a striped bass that was tagged at the SWP Horseshoe Bend release site in October 2007 and was last detected at Mare Island in March 2008.

Table 12- Predatory fish species tagged with acoustic transmitters

Species	Tag #	Location tagged	Date tagged	Last date Detected	Location of last detection (see Figure 8)
Striped bass	3283	HS	8/23/2007	8/24/2007	Sac R. SW of Decker Is.
Striped bass	3420	HS	8/23/2007	8/25/2007	HS
Sacramento pikeminnow	3290	HS	8/23/2007	11/3/2007	Rio Vista Br.
Sacramento pikeminnow	3288	HS	8/23/2007	4/2/2008	CS2
Sacramento pikeminnow	3292	HS	8/23/2007	4/17/2008	HS
Sacramento pikeminnow	3286	HS	8/23/2007	10/3/2007	EMM
Sacramento pikeminnow	3426	HS	8/23/2007	12/1/2007	CS2
Sacramento pikeminnow	3284	HS	8/23/2007	2/27/2008	Sac R. SW of Decker Is.
Sacramento pikeminnow	3291	HS	8/23/2007	4/17/2008	EMM
Sacramento pikeminnow	3424	CL	8/23/2007	9/3/2007	CL
Striped bass	3419	HS	10/26/2007	3/3/2008	SAC
Striped bass	3287	HS	10/26/2007	3/25/2008	SAC
Striped bass	3423	HS	10/26/2007	11/8/2007	Three Mile Slough
Striped bass	1387	HS	10/26/2007	3/3/2008	Mare Island
Sacramento pikeminnow	1385	HS	10/26/2007	4/17/2008	EMM
Sacramento pikeminnow	3425	HS	10/26/2007	3/7/2008	HS
Sacramento pikeminnow	3293	HS	10/26/2007	2/10/2008	Sac R. Mouth
Sacramento pikeminnow	1386	HS	10/26/2007	2/11/2008	Sac R. above Ord Br.
Sacramento pikeminnow	3417	CS1	12/13/2007	4/17/2008	CS1
Sacramento pikeminnow	3418	CS1	12/13/2007	1/4/2008	Rio Vista Br.
Sacramento pikeminnow	3415	HS	12/14/2007	3/19/2008	Georgiana Sl.
Sacramento pikeminnow	3296	CL	12/13/2007	1/8/2008	DB
Sacramento pikeminnow	3416	CL	12/21/2007	3/6/2008	DB
Sacramento pikeminnow	3305	CL	12/21/2007	4/16/2008	CL
Sacramento pikeminnow	3367	CL	2/19/2008	3/24/2008	EMM
Sacramento pikeminnow	3371	CS1	2/26/2008	4/17/2008	CS2
Sacramento pikeminnow	3369	CS1	2/26/2008	4/17/2008	CS1
Striped bass	3375	CS1	3/26/2008	4/3/2008	Georgiana Sl.

Table 13- Site fidelity of adult striped bass tagged with acoustic transmitters at the SWP Horseshoe Bend release site in 2007 and 2008

Tag ID	Date tagged	Last date of detection	No. of days detected at release site post tagging	No. of days monitored	% of total monitoring days detected at release site post tagging
1387	10/26/2007	3/3/2008	1	175	0.6
3283	8/23/2007	8/24/2007	1	239	0.4
3287	10/26/2007	3/25/2008	2	175	1.1
3419	10/26/2007	3/3/2008	2	175	1.1
3420	8/23/2007	8/25/2007	3	239	1.3
3423	10/26/2007	11/10/2007	3	175	1.7
					Mean= 1%

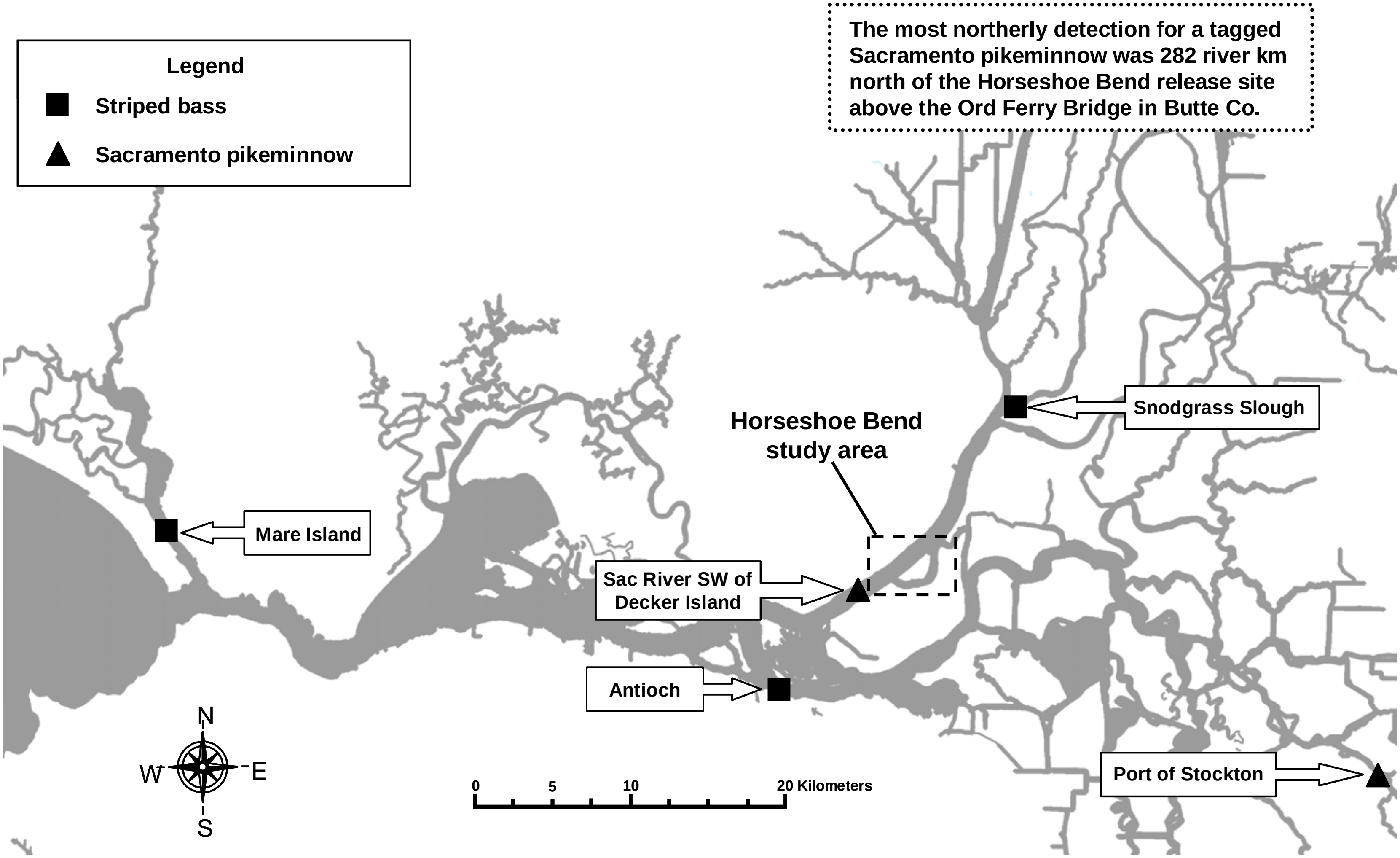
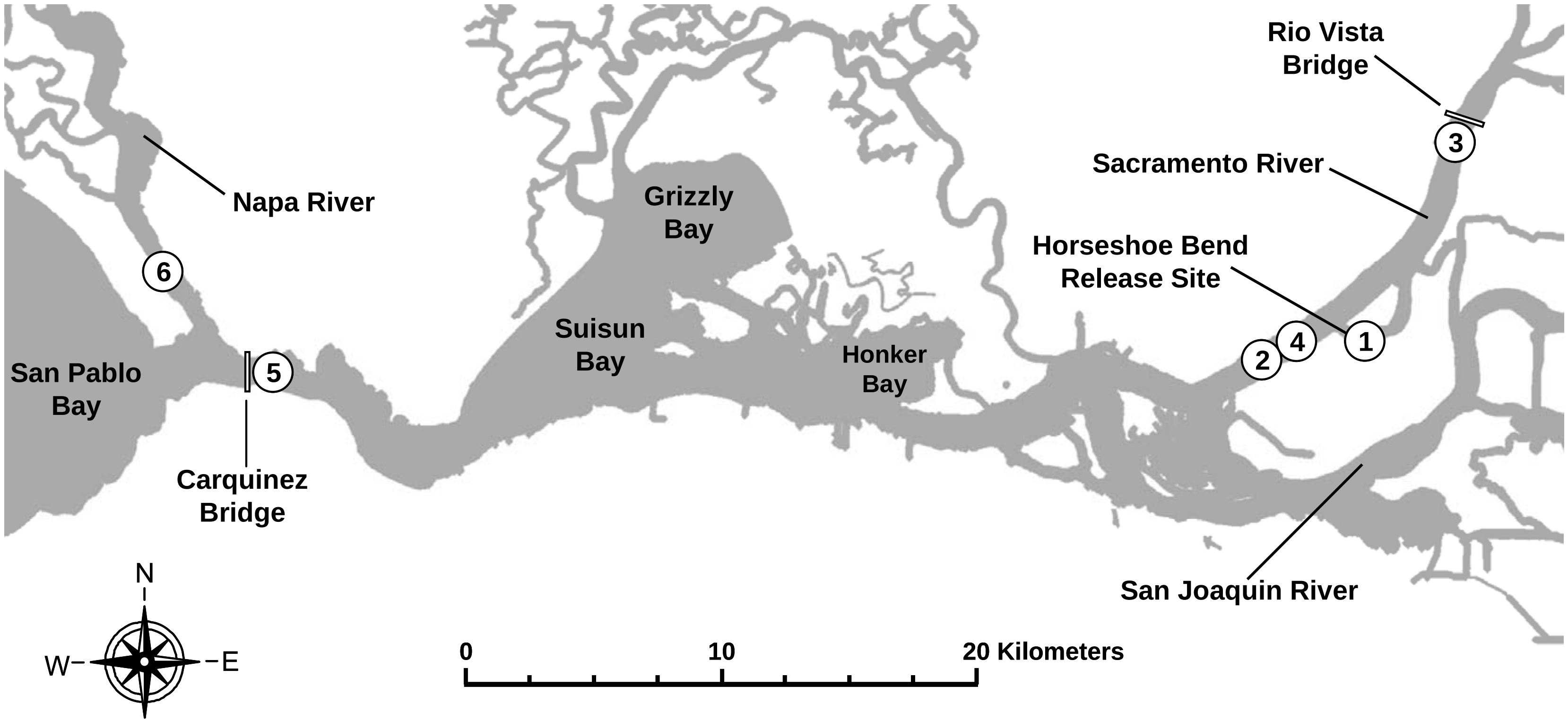


Figure 15- Detections outside of the Horseshoe Bend study area for acoustic-tagged adult striped bass and Sacramento pikeminnow between August 2007 and April 2008. Fish were detected as far north as the Sacramento River at river km 282, as far west as Mare Island, and as far east as the Port of Stockton.

Striped Bass – Tag # 1387



1. 10/26/07: Tagged and released at Horseshoe Bend release site
2. 10/27/07 to 11/6/07: Sacramento River southwest of Decker Island
3. 11/8/07 to 11/10/07: Rio Vista Bridge
4. 2/12/08 to 2/13/08: Sacramento River southwest of Decker Island
5. 2/14/08 to 2/16/08: Carquinez Bridge
6. 2/18/08 to 3/3/08: Mare Island (last detection)

Figure 16- Movement of striped bass #1387 after being acoustic-tagged and released at the SWP Horseshoe Bend release site

Adult Sacramento pikeminnow with acoustic transmitters captured and released at the SWP release sites were generally observed to have more site fidelity than striped bass. Those tagged at the Horseshoe Bend site were detected between < 1% and 85% of the days monitored in the vicinity of the release site (Table 14). Those pikeminnow tagged at the SWP Curtis Landing release site were detected between 1.7% and 51% of the time in the vicinity of the release site (Table 14). Unlike many of the tagged striped bass that moved westerly towards San Pablo Bay, the majority of tagged Sacramento pikeminnow left the Horseshoe Bend area and were detected on the Consortium receivers moving up the Sacramento River. Five pikeminnows tagged at the SWP Horseshoe bend release site eventually left the study area and were detected in Steamboat Slough (Sacramento Co.). One of these pikeminnows returned to the Horseshoe Bend area after traveling to Steamboat Slough. Between August 2007 and April 2008, acoustic-tagged pikeminnow were detected as far north as above the Ord Ferry Bridge (Butte Co.), as far south and east as the port of Stockton (San Joaquin Co.), and only as far west as Antioch and the Sacramento River just downstream of Horseshoe Bend (Sacramento Co.; Figure 15). The pikeminnow that traveled upstream of the Ord Ferry Bridge was last detected at that location in mid-February 2008 (Figure 17).

Four Sacramento pikeminnow were tagged outside of the release sites at Control Site 1. Although these fish were detected at each of the receivers within Horseshoe Bend, all of these fish spent the highest percentage of time within the Control Site 1 area.

Based on Mann-Whitney Rank Sum analysis results, the proportion of time that Sacramento pikeminnow resided at a release site was not the same as for striped bass ($U=87.500$, $p=0.012$). Tagged striped bass typically spent very little time at the release site before moving out of the area (Table 13).

The number of predators large enough (>300 g [0.66 lb]) for tagging with acoustic transmitters declined at both the SWP Horseshoe Bend and Curtis Landing release sites, during the course of the study. This may have been due to the number of fish salvaged at the state and federal fish salvage facilities, which normally tend to decline during the late-fall and winter months. Figure 18 shows a declining trend of total fish released at the SWP release sites during the study period. DWR staff at the SDFPF provided fish release data used in the figure.

Table 14- Site fidelity of adult Sacramento pikeminnow tagged with acoustic transmitters at the SWP Horseshoe Bend and Curtis Landing release sites in 2007 and 2008

Tag ID	Tag location	Date tagged	Last date of detection	No. of days detected at release site post-tagging	No. of days monitored	% of monitoring days detected at release site post-tagging
1385	Horseshoe Bend Release Site	10/26/2007	4/17/2008	10	175	6
1386	Horseshoe Bend Release Site	10/26/2007	2/11/2008	24	175	14
3284	Horseshoe Bend Release Site	8/23/2007	2/27/2008	88	239	37
3286	Horseshoe Bend Release Site	8/23/2007	10/3/2007	24	239	10
3288	Horseshoe Bend Release Site	8/23/2007	4/2/2008	1	239	0.4
3290	Horseshoe Bend Release Site	8/23/2007	11/7/2007	16	239	7
3291	Horseshoe Bend Release Site	8/23/2007	4/17/2008	2	239	0.8
3292	Horseshoe Bend Release Site	8/23/2007	4/17/2008	202	239	85
3293	Horseshoe Bend Release Site	10/26/2007	2/10/2008	1	175	0.6
3415	Horseshoe Bend Release Site	12/14/2007	3/19/2008	93	126	74
3425	Horseshoe Bend Release Site	10/26/2007	3/11/2008	136	175	78
3426	Horseshoe Bend Release Site	8/23/2007	12/4/2007	24	239	10
3296	Curtis Landing Release Site	12/13/2007	1/8/2008	10	127	8
3305	Curtis Landing Release Site	12/21/2007	4/16/2008	42	119	35
3367	Curtis Landing Release Site	2/19/2008	3/24/2008	30	59	51
3416	Curtis Landing Release Site	12/21/2007	3/6/2008	23	119	19
3424	Curtis Landing Release Site	8/23/2007	9/3/2007	4	239	1.7
						Mean= 25.7%

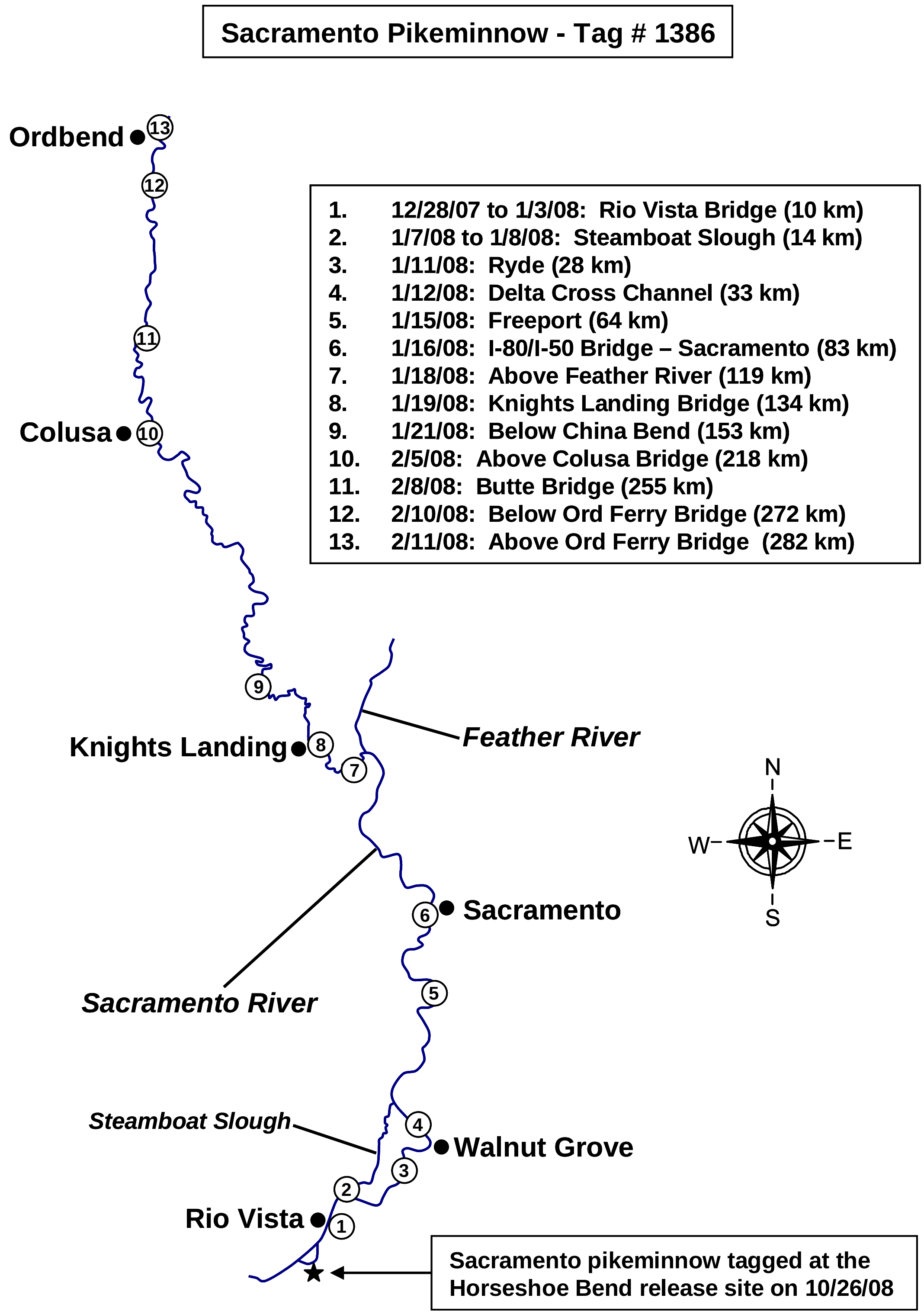


Figure 17- Movement of Sacramento pikeminnow #1386 in the Sacramento River and distances traveled from the SWP Horseshoe Bend release site

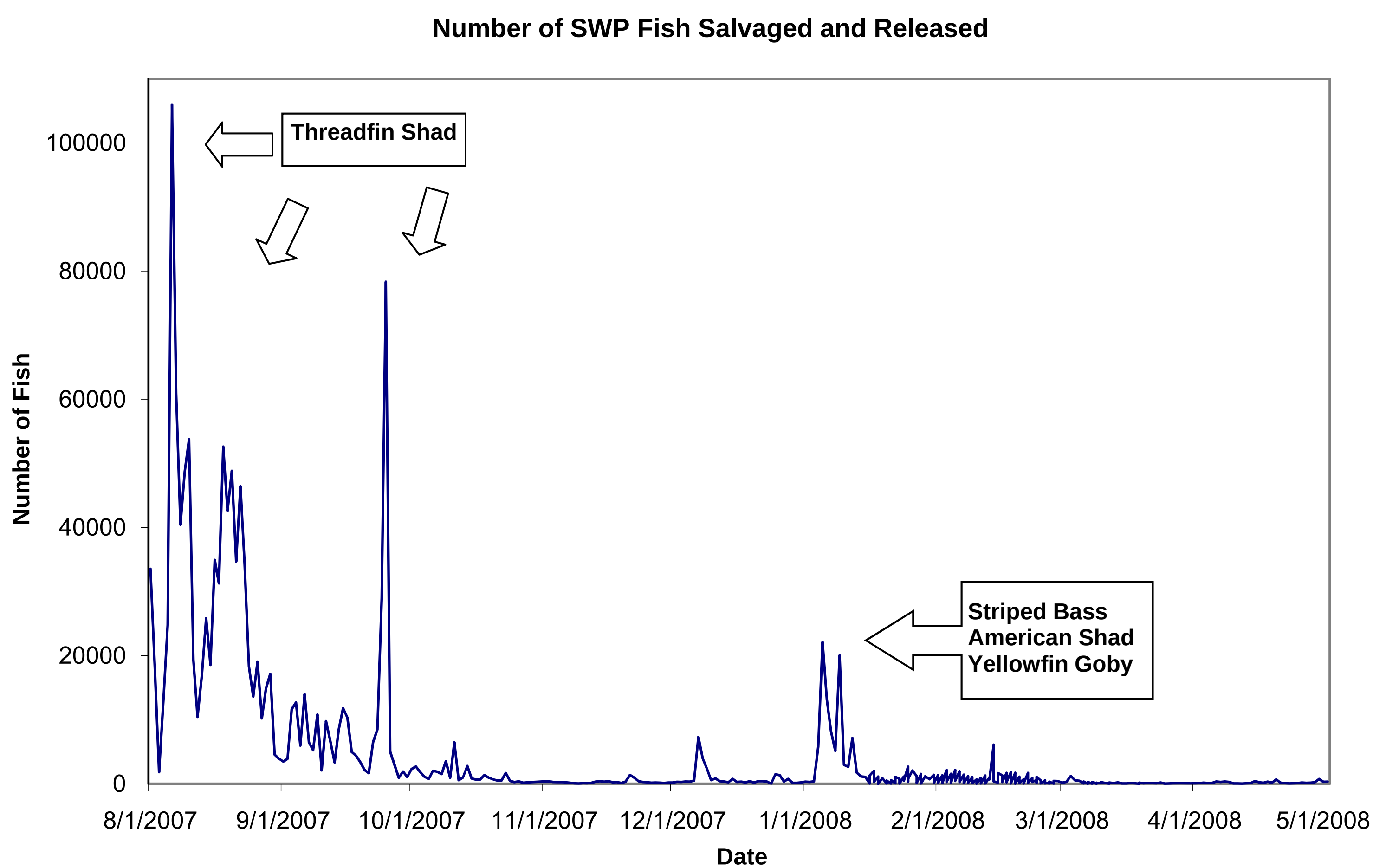


Figure 18- Numbers of salvaged fish transported from the SDFPF and released at the SWP release sites from August 1, 2007, to May 1, 2008. Predominant species being salvaged during peak events are shown in boxes with arrows.

Hourly water temperature and conductivity readings for the Emmaton CDEC site were used to observe whether water quality affected the movement of acoustic-tagged Sacramento pikeminnow (Appendices 11.3 & 11.4). Many of the pikeminnow were sedentary and did not move from near their release points. Although many of the pikeminnow showed a slight tendency to move upstream when water conductivity increased, movement in relation to water temperature was quite variable. Striped bass movement was not compared to Emmaton water quality readings as the striped bass tagged with acoustic tags during the study tended to leave the Horseshoe Bend area within days of tag and release.

2.4 Discussion

Sacramento pikeminnow, striped bass, and some members of the centrarchid family (largemouth bass, bluegill, and black crappie) were the predominant predatory fish species collected during electrofishing. Pickard and others (1982) found striped bass and Sacramento pikeminnow to be the most numerous predators in the Horseshoe Bend area from 1976 to 1978. Unlike the 1976 study, this study did not capture any channel catfish (N=0) and only a handful of white catfish (N=6). This disparity was largely due to the different sampling types used for both studies. This study used electrofishing, which is generally ineffective at capturing catfish in deep water, while Pickard and others used gill netting, a gear type that is more effective at catching the bottom oriented catfish species. Other studies (Orsi 1967) showed black crappie to be more abundant and slightly larger (most fish greater than 160 mm [6.3 in] FL) at their test site (SWP Horseshoe Bend release site) than this study. Again, the different sampling gear used in this study (electrofishing) versus Orsi’s (gill netting) might have explained the variation in number and size of black crappie. Another explanation for the differences in species abundance and size of black crappie might be due to the changes in the local population during the 40 years separating these studies.

Catch data for largemouth bass showed that among piscivorous fish, this species had the greatest presence at the SWP Horseshoe Bend release site. Recapture data suggested site fidelity for this species, as all largemouth bass recaptures were made at the same location of tagging and releasing. Moyle (2002) stated adults were mostly piscivorous and considered them a keystone predator, whose foraging could alter the ecosystem and the population of its desired prey. Although no largemouth bass were caught in the immediate vicinity of the release pipe, the pilings supporting the pipe and submerged trees in the area provides habitat that is highly desired by this species. Largemouth bass might also be a major source of predation on salvaged fish as the salvaged fish disperse up and downstream from the release sites and potentially move into the near shore habitat characterized by extensive largemouth bass habitat. The available habitat, abundance data, site fidelity data, and adult selectivity for prey fish, suggest this predator could potentially contribute to the predation of released salvaged fish. Higher spatial resolution telemetry studies are needed to determine its contribution to post-release predation.

Telemetry results indicated that many of the Sacramento pikeminnow tagged at the SWP Horseshoe Bend release site remained in the vicinity of the release site for some period of time (less than a month to several months) before either moving into the main stem of the Sacramento River or elsewhere within Horseshoe Bend. Acoustic-tagged striped bass did not demonstrate much site fidelity to the SWP Horseshoe Bend release site as these fish only spent one to three days at the release site before moving out of the area. The tag detection data showed that striped bass would tend to migrate within a few days of tagging to the main river and travel as far downstream as Carquinez Strait before returning to the release sites in the early spring

Due to inherent limitations of the tagging technology used, this study could not determine if predatory fish are attracted to the release sites from the surrounding area when salvaged fish are released. Attempts made before the start of the study to attenuate the VR2 receivers and compress the range of detection were unsuccessful. Therefore, although acoustic-tagged predators were detected at the Horseshoe Bend receivers during the time of a fish release, we could not determine how close these predatory fish were to the release pipe during fish releases.

Each of the acoustic-tagged predatory fish eventually moved out of the area where they were tagged. Some of the tagged fish tended to move short distances away from their tagging location, while others moved as far away as San Pablo Bay and the upper reaches of the Sacramento River. Moyle (2002) reported that Sacramento pikeminnow are capable of living either a sedentary life style or migrating long distances. Both types of life strategies were observed in our release site study. A few pikeminnow stayed in close proximity to the location they were tagged for up to four months while others traveled as far as 282 km (175 mi) up the Sacramento River. Striped bass tended to leave the area where they were tagged within a few days.

Movement of Sacramento pikeminnow appeared to be slightly influenced by water temperature and conductivity around the Horseshoe Bend area. Most of the pikeminnow showed a slight tendency to move upstream with an increase in conductivity, which was expected for this species of fish. Pikeminnow response to water temperature was inconsistent as some fish had a tendency to move slightly upstream when temperatures increased while others would move slightly downstream. Movement of striped bass in the Horseshoe Bend area in relation to water quality could not be examined due to their lack of site fidelity.

Unfortunately, the monitoring schedule (August 2007-April 2008) did not incorporate the late spring and early summer. Therefore, the hypothesis that predators would congregate at the release site during a period which often the highest densities of prey fish are released could not be tested for this time period.

2.5 Conclusions

The results of the predatory fish tagging and sampling component of the study suggest that while striped bass have traditionally been the predatory species of greatest concern, Sacramento pikeminnow and largemouth bass should also be considered as potential predators on salvaged fish. Both the large number collected and site fidelity of both of these species suggests that they may be major contributors to losses of salvaged fish. Given this finding, future modifications to the release sites or design of new release sites should take these two species and their respective life histories into consideration. For example, efforts should be taken to place release sites at locations that lack extensive centrarchid habitat (ie. aquatic vegetations beds, submerged structure).

3.0 Avian Predation

Predation by birds may represent a large source of mortality of salvaged fish. Birds have high metabolic rates and require large quantities of food relative to their body size (Ruggerone 1986). Most piscivorous birds that have been observed within the study area are colonial nesting birds including, but not limited to Great Blue Heron (*Ardea herodias*), Western Grebe (*Aechmophorus occidentalis*), Clark's Grebe (*Aechmophorus clarkia*), Great Egret (*Ardea albus*), Snowy Egret (*Egretta thula*) Double-crested Cormorant (*Phalacrocorax auritus*), and several species of gulls (*Larus californicus, L. delawarensis, L. smithsonianus, L. occidentalis*). These species are particularly suited to the exploitation of fluctuating prey fish densities (Alcock 1968, Ward and Zahavi 1973). Such prey fish density fluctuations can result from large migratory accumulations, hatchery releases, physical obstructions that concentrate or disorient fish, and other natural features and events which occur in complex river systems (Stephenson and Fast 2004). Therefore the potential for salvaged fish releases, which are similar to hatchery releases, to be exploited by piscivorous birds is high.

In order to examine the magnitude of avian predation occurring at the salvaged fish release sites, a piscivorous bird survey was conducted in conjunction with DIDSON monitoring of piscivorous fishes. This survey had the following objectives:

- Document the presence, abundance, and behavior of predatory birds at the salvaged fish release sites and two control sites.
- Determine if predatory bird abundance is elevated at the salvaged fish release sites in contrast with two reference sites.
- Determine what factor(s) may be contributing to increased salvaged fish vulnerability to avian predation at the release sites.

Knowing the level of avian predation on salvaged fishes would help determine the need to reduce such predation as part of any predator reduction solutions at the salvaged fish release sites.

3.1 Methodology

A minimum of five bird surveys were planned at each release site during each of the five monitoring periods (Table 1) for a total of 25 surveys/site. Bird surveys at the SWP Horseshoe Bend release site were conducted at three times during the release process: 30 minutes before the release-truck arrival, during the release from the time that the truck arrived until its departure, and 30 minutes after the release. Surveys consisted of identifying (to family) and enumerating all piscivorous birds in the immediate vicinity of the release pipe, defined as the area in a 50-m (164 ft) radius of the release pipe. In addition, we noted predatory behavior such as diving, feeding, floating or hovering. A pair of 8 x 42 power binoculars was used for all observations. We conducted surveys in conjunction with fixed DIDSON monitoring at the SWP Horseshoe Bend release site, therefore the timing of surveys corresponded to the timing of releases as dictated by SWP pumping and salvage operating procedures. During the study, survey events typically occurred from 8 a.m. to noon.

Bird surveys at all other sites (CVP Emmaton, SWP Curtis Landing, Control Sites 1 & 2) were conducted immediately before DIDSON mobile monitoring at each site. As the boat approached the site, the boat operator stopped the boat well away from the site and the survey was conducted to avoid scaring away any birds. Surveys consisted of identifying (to family) and enumerating all piscivorous birds present and noting any predatory or foraging behavior. A pair of 8 x 42 power binoculars was used for all observations. The timing of these surveys was random and typically occurred anywhere from 8 a.m. to 1 p.m.

All data were entered into a Microsoft Access database and checked line by line for any data entry errors. For the purpose of comparisons between sites, the “30 minutes prior to release” observations for the SWP Horseshoe Bend site were used to compare to the other sites since those observations represented the maximum possible amount of time since the previous release event. The release period and 30 minutes after release count data were used only for analyses of behavior and distribution during releases. Of the birds observed during our monitoring, only cormorants and gulls had sufficient numbers for any discussion of behavior.

3.2 Results

3.2.1 Species Composition and Abundance

Cormorants, grebes, gulls, herons, and egrets were the piscivorous bird families present in the study area (Table 15). Most birds were at the SWP Horseshoe Bend release site or at the CVP Emmaton release site. The control sites and the SWP Curtis Landing release site consistently had few if any birds present (Figure 19). Gulls were very abundant during the first two monitoring periods (August and October) then slowly tapered off as the study progressed. Cormorants were abundant at the SWP Horseshoe Bend release site only, with exception of the first monitoring period. Grebes, herons, and egrets were sporadically present at several of the release sites, but were never consistently observed.

Table 15- Mean numbers of various avian predators in the study area for each of the 5 monitoring periods (Table 1).

		Monitoring Period				
Species	**Site**	**1**	**2**	**3**	**4**	**5**
Cormorants	Control 1	0	0	0	0	0
	Control 2	0	0	0	0	0
	Curtis	0	0	0	0	0
	Emmaton	0	0	0	0.4	0
	HSB	0	1.4	9.2	3.4	9
Gulls	Control 1	0	0.2	0	0	0
	Control 2	0	0	0	0	0
	Curtis	0	0	0	0	0
	Emmaton	0	18	4.16	2	0
	HSB	10.2	4.2	0.4	0.4	0.25
Grebes	Control 1	0	0	0	0	0
	Control 2	0	0.2	0	0	0
	Curtis	0	0	0	0.25	0.2
	Emmaton	0	0	0	0.6	0.25
	HSB	0	0	0	0	0
Egrets	Control 1	0.2	0.2	0	0	0
	Control 2	0	0.2	0	0	0
	Curtis	0	0	0	0.25	0
	Emmaton	0	0.8	0	0.2	0.25
	HSB	0	0	0	0	0
Herons	Control 1	0	0	0	0	0
	Control 2	0	0	0	0	0
	Curtis	0.2	0	0	0.25	0
	Emmaton	0	0	0	0	0
	HSB	0.2	0	0	0	0

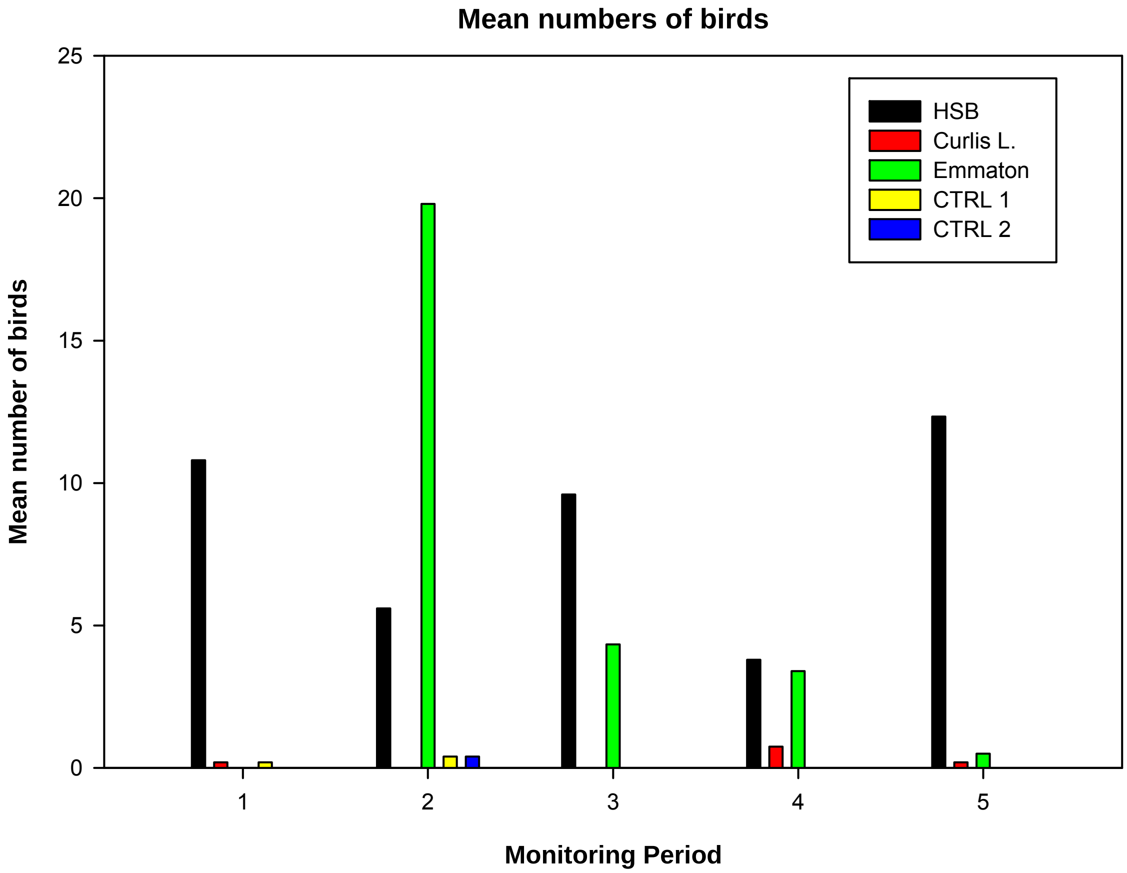


Figure 19-Mean numbers of piscivorous birds present at each of the five survey sites during the study

Control Site 1
Twenty-five surveys were conducted at Control Site 1, five surveys during each monitoring period (Table 1). Birds were generally rare and only present at Control Site 1 during the first two monitoring periods. Three birds were observed consisting of an egret during monitoring period 1 which was wading in the tules adjacent to the intake structure, 1 gull observed hovering high above the site and an Egret wading in the tules adjacent to the intake during monitoring period 2.

Control Site 2
Twenty-five surveys were conducted at Control Site 2, five surveys during each monitoring period (Table 1). Birds were rarely observed and only present during the second monitoring period. Two birds were observed including a grebe swimming on the surface approximately 20 m (65 ft) away from the shoreline, and an egret perched on the intake structure.

SWP Curtis Landing Release Site
Twenty-four surveys were conducted at the SWP Curtis Landing release site, five surveys during each monitoring period (Table 1) except monitoring period 4 when only four surveys were conducted due to poor weather conditions. Birds were generally rare at Curtis Landing.

SWP Horseshoe Bend Release Site
We did 24 surveys at the SWP Horseshoe Bend release site, five surveys during each monitoring period (Table 1) except monitoring period 5 when only four surveys were conducted due to poor weather. The Horseshoe Bend release site consistently had the highest number of total birds of all the study sites and was the only site where Cormorants were consistently observed. As many as 13 cormorants (3/26/08) and 22 gulls (8/9/2007) were observed feeding during releases at the Horseshoe Bend release site. Birds of all other species were generally rare at the Horseshoe Bend release site with the exception of several herons observed during the first monitoring period.

CVP Emmaton Release Site
Twenty-three surveys were conducted at the CVP Emmaton release site, five surveys during each monitoring period (Table 1) except monitoring period 1 when consistently high winds only allowed for three surveys. The CVP Emmaton release site on occasion had large numbers of gulls present. As many as 35 gulls (10/18/07) were observed within the vicinity of the site. However, the presence of large numbers of gulls was often associated with nearby sea lion feeding activity. Interestingly, cormorants were only observed on one occasion, January 29, 2008, even though they were commonly observed just upstream at the SWP Horseshoe Bend release site.

3.2.2 Behavior during Releases

Gulls
At both the SWP Horseshoe Bend and CVP Emmaton release sites, true predatory behavior by gulls was difficult to differentiate from scavenging behavior during releases. In addition to live salvaged fish, the fish release truck typically has many dead or dying fish and various other debris (ie. Aquatic weed, trash, woody debris). Gulls were observed pecking and diving at floating objects. They were often observed fighting over floating fish, but it was unclear whether these fish were dead, injured, or simply disoriented. Anecdotal observations from the Element 3 experiments indicate that on occasion, salvaged fish may exit the release pipe and become disoriented. On several occasions, fish in experimental releases were observed swimming in circles at the surface for several minutes after the release but were shown to recover. If fish are simply injured or disoriented, they conceivably could survive if not for predation by the gulls. At both sites, birds typically followed the plume of salvaged debris/fish as it dispersed up or downstream (depending on the tide) from the release site until it was ~100 meters (328 ft) away from the release site, at which time the gulls either dispersed or returned to their perches.

At the SWP Horseshoe Bend release site, gulls (when present) consistently perched on the support structure of an agricultural water intake located adjacent to the release pipe (Figure 20). The support structure provides an elevated resting and vantage point that gulls utilized to observe release activities and to rest between releases. A sunken dock just downstream of the release pipe was rarely used as a perch, possibly due to its limited elevation above the water line.

At the CVP Emmaton release site, gulls were often observed perched on the hand rails of the catwalk above the release pipe before, during, and after releases. During the second monitoring period, on several occasions large aggregations of gulls (15-20) were also observed shadowing the movements of sea lions present in the area and presumably scavenging. The presence of the sea lions may explain why birds were so abundant at the CVP Emmaton site during the second monitoring period.

Figure 20-Piscivorous birds (gulls) perched on a pump intake structure adjacent to the SWP Horseshoe Bend release site

Cormorants

Active feeding by cormorants was only observed at the SWP Horseshoe Bend release site. Successful predation on salvaged fish was confirmed by DIDSON observations of cormorants catching fish as they exited the release pipe (Figure 21). The same video footage also showed that while the cormorants often momentarily scared away any nearby predatory fish, they did not appear to be actively pursuing the predatory fish but rather were focused on capturing salvaged fish. Any predatory fish displaced by the cormorants quickly returned to their position near the release pipe once the cormorant was gone. Several cormorants were also observed surfacing near the release pipe with prey of appropriate size for salvaged fish. Active feeding by cormorants at the release site was characterized by cormorants floating near the end of the pipe then making long (~30 second) dives in the vicinity of the pipe. When releases occurred during strong tides and correspondingly higher water velocities, cormorants were observed positioning themselves farther upstream or downstream from the pipe in an effort to compensate for the additional sweeping flow.

As with the gulls, cormorants (when present) used the agricultural intake structure adjacent to the SWP Horseshoe Bend release site as a perch. Observations of 12–13 cormorants perched on the structure were common. As with the gulls, cormorants did not use the partially sunken dock downstream of the release site. Interestingly, cormorants were rarely observed at the CVP Emmaton release site even though they were so common at the SWP Horseshoe Bend release site which is located just upstream.

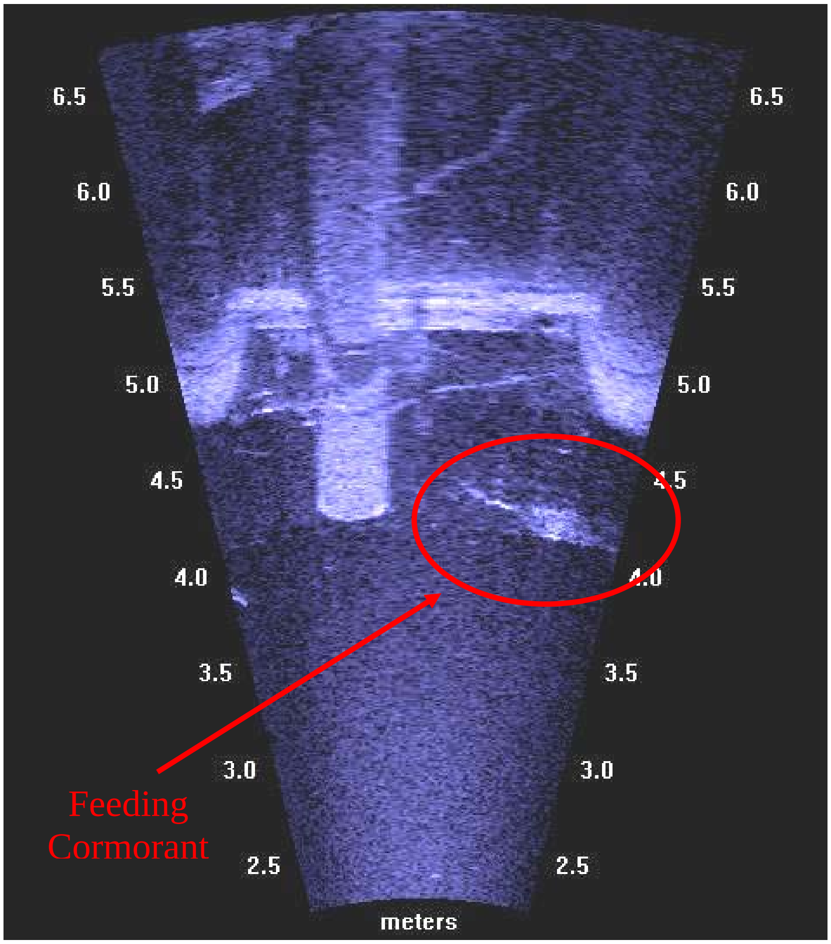


Figure 21- DIDSON image showing a cormorant feeding at the end of the SWP Horseshoe Bend release pipe

3.2.3 Learned Behavior and Behavioral Attraction

For both gulls and cormorants, many birds used the agricultural intake structure adjacent to the SWP Horseshoe Bend release site as a perch at some point before, during, or after a release. Typically, as the release truck arrived at the site, some if not all of the birds would leave their perch and either hover above the site (gulls) or float on the water's surface near the end of the pipe (cormorants and some gulls), suggesting that the arrival of the truck was a visual cue for the birds. When the salvage operator climbed aboard the top of the truck to rinse the tank, in most cases birds still perched on the intake structure used this as another cue to leave their perch and begin searching for prey. Actively feeding birds were not encountered at the SWP Curtis Landing release site or at either of the control sites.

3.3 Discussion

Elevated numbers of avian predators were observed at two of the three release sites monitored, and were directly linked to predation on salvaged fishes through visual and DIDSON observations. The avian predation component of this study showed that cormorants and gulls were the primary avian predators of salvaged fishes at the time of release. This is not surprising, because bird species of both families are known to take advantage of artificially created aggregations of prey fishes such as hatchery releases and dam spillways (Alcock 1968, Ward and Zahavi 1996). When a release is conducted, a turbulent plume of water extends from the point within the submerged pipe that the released water impacts the receiving water to near the terminus of the release pipe, possibly extending to beyond the end of the pipe. As fish pass through this area, they could be disoriented and become more susceptible to predation by both fish and avian predators. Furthermore, cormorants are efficient, subsurface predators and gulls are efficient surface scavengers on disoriented or injured fish.

Interestingly, cormorant abundance increased as numbers of salvaged fish decreased (Table 15). Seasonal abundance of cormorants and seasonal migration may have been a reason for this discontinuity between abundance of cormorants and salvaged fish. Double Crested Cormorants usually arrive at their wintering grounds, including the Delta, in November and remain there until April, then move back to their home range (Aderman and Hill 1995, DWR 2009). This suggests that the cormorants observed feeding at the release sites were not permanent residents of the area, but rather a transient population. This also explains the absence of cormorants from the study area during the first (August) monitoring period. Another possibility is that cormorant predation was tied to the species composition at that location in the Delta and that they may have been there based on the presence of particular prey species. For example, the period that most cormorants were observed (winter/early spring) corresponds to the period of highest juvenile salmonid abundance in the Delta (steelhead and Chinook salmon smolts). In the Columbia River basin, Double-crested Cormorants have been shown to feed heavily on out-migrating salmonids (Collis and others 2001). Another study found that cormorants' strong affinity for salmonids is exhibited by distributing themselves wherever trout fingerlings were located in a reservoir and by consuming mostly trout despite presence of many other fish (Modde and Wasowicz 1996).

Cormorants are widely recognized as being an efficient avian piscivore. Cormorants are capable of consuming up to a third of their body weight per day (Robertson 1974). At the SWP Horseshoe Bend release site, predation by cormorants on salvaged fish was confirmed by DIDSON observations of several cormorants chasing and/or capturing small fish as they exited the release pipe. In addition, cormorants were often observed surfacing near the release pipe with fish in their mouths. While the total number of fish eaten by the cormorants is unknown, the proportion of salvaged fish eaten could be substantial. During the period that cormorant abundance is highest, salvaged fish releases often consist of only a few hundred fish, therefore even a seemingly modest number of salvaged fish lost to avian predation may be a substantial proportion of the total number of salvaged fish.

3.4 Conclusions

The results of the avian predation component of the study show that predation by birds on salvaged fish could potentially have a major impact on salvaged fish survival. Most cormorants were observed feeding on salvaged fish during a season when the fewest numbers of the salvaged fish are released, coinciding with the critical juvenile salmon and steelhead outmigration season. As a result, even only a few birds could have a substantial impact on the percentage of salvaged fish surviving release.

The results of the avian predation component also showed that birds were adept at taking advantage of any structures at or around the release sites as roosting sites or perches. The various structures at the SWP Horseshoe Bend release site and CVP Emmaton release site appeared to make ideal perches for a number of birds. Conversely, the lack of any perches at the SWP Curtis Landing release site, resulted in few birds being observed there even though the number of salvaged fish being released was similar. As a guideline for the construction and placement of new or refurbished release sites, all possible roosting sites or perches near the release sites should be either removed or equipped with bird deterrent devices, such as bird spikes. Similarly, release sites should not be placed near any partially submerged structures, such as snags or agricultural intakes, that might provide roosts/perches for piscivorous birds. Efforts should also be made to remove any exposed snags that get lodged near the release sites.

4.0 DIDSON Observations

The **D**ual frequency **ID**entification **SON**ar, or DIDSON™, is a high-definition imaging sonar designed by the University of Washington's Applied Physics Lab for military applications such as diver detection and underwater mine identification and marketed by the Sound Metrics Corporation (Lake Forest Park, WA). The DIDSON camera system provides a valuable observational tool that can be used to assess changes in predator behavior and density at the study sites. DIDSON operates at two frequencies, 1.8 MHz for close range observations of less than 12 m (40 ft) and 1.0 MHz for detecting targets at ranges up to 40 m (130 ft). At close ranges, this sonar gives near video quality images for identifying objects underwater. The camera emits 48 beams of sound in the low frequency mode and 96 beams of sound in high frequency mode for a 29 degree field of view for both frequencies. The camera uses the sound waves to detect acoustic echoes of objects in the water and then converts them into digital images, which can be viewed on a computer. These same sound waves give DIDSON the ability to produce clear images in dark or turbid waters, unlike standard underwater cameras that rely on a light source to produce an image. The images produced by DIDSON are very similar to an ultrasound image (Figure 22).

The DIDSON camera was used to document predator behavior and abundance at the exit of the salvaged fish release pipes at the SWP Horseshoe Bend, SWP Curtis Landing, and CVP Emmaton release sites. In addition, DIDSON observations were conducted at the two control sites to compare predator abundance and behavior to submerged underwater structures without the added attraction of fish releases. As a result of the DIDSON camera's limited field of vision, the use of the camera was intended to complement the greater range capability of the split beam hydroacoustic system also used in the study.

The DIDSON was also used to make detailed observations of the release process at the SWP Horseshoe Bend release site. These observations included predator behavior in response to specific events during the release process including the arrival of the release truck, activation of the flushing system, and the exit of salvaged fish into the receiving water. Measurements of fish length, while possible using the DIDSON software, were not conducted due to the absence of any literature on the accuracy or error associated with these measurements.

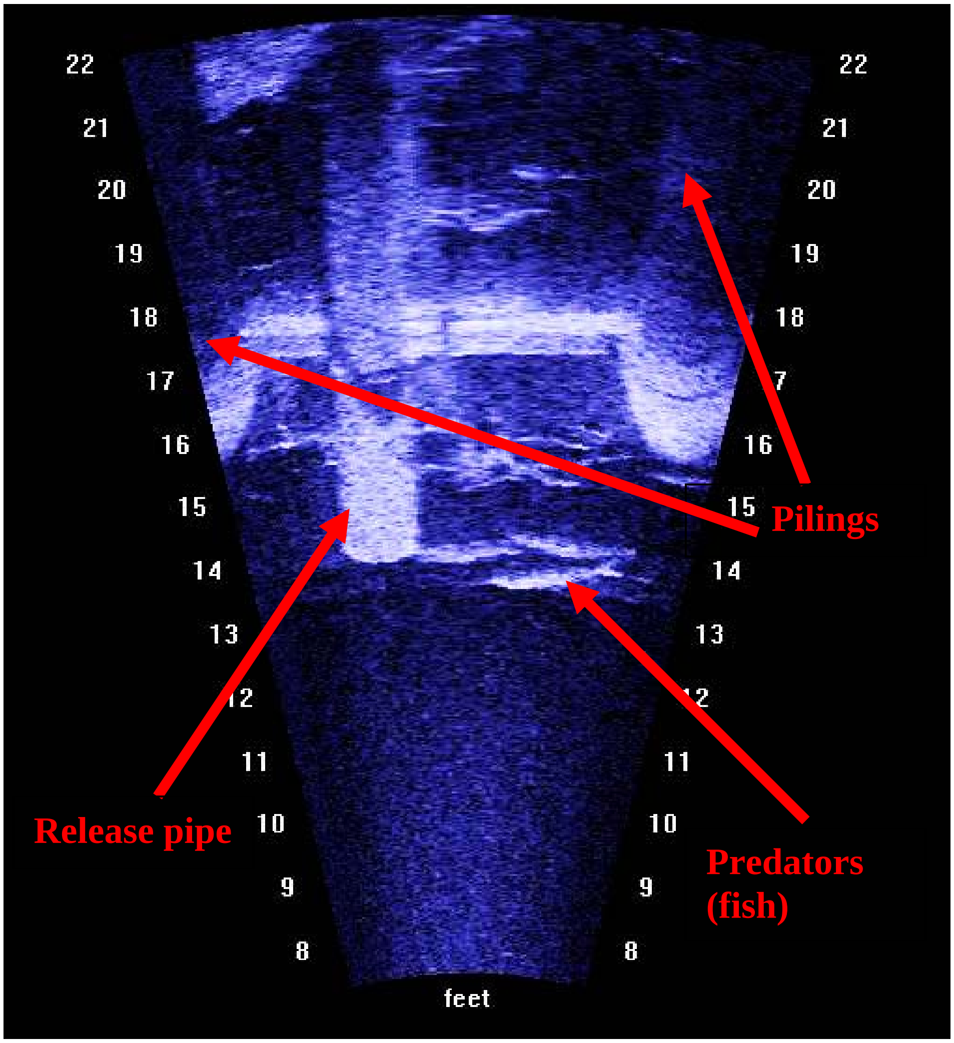


Figure 22- Example of imagery produced by the DIDSON camera with important features pointed out.

4.1 Methodology

DIDSON monitoring was conducted as a combination of "Fixed Site" monitoring at the SWP Horseshoe Bend release site and "Mobile" monitoring at all other sites. The installation of permanent camera deployment facilities at the SWP Horseshoe Bend release site allowed for detailed observation of salvaged fish released at the site.

4.1.1 Fixed Site Monitoring

Monitoring at the SWP Horseshoe Bend release site was conducted five times during each monitoring period (Table 1). Permanent DIDSON deployment equipment was installed at this site that allowed the DIDSON camera to be positioned at a fixed location to determine predator behavior in the immediate vicinity of the release pipe. The field of view for the DIDSON camera was fixed at one location throughout the observational period to determine changes in predator behavior before, during, and after releases. With a fixed field view, relative predator abundance was measured and observations were also used to assess changes in predator behavior and behavioral attraction to the release pipe discharge location.

The permanent DIDSON mounting equipment installed at the SWP Horseshoe Bend release site consisted of a galvanized steel boom that could be lowered and raised with a winch. At the end of the boom, a 3 m (10 ft) steel pole with a mounting bracket for the DIDSON camera on one end was attached (Figures 23 & 24). This configuration placed the DIDSON camera at a range of 4.25 m (14 ft) from the end of the release pipe and at an optimal viewing angle. A data/power cable for the DIDSON camera was also deployed that allowed for operation of the DIDSON camera from onshore within the release site compound. During each monitoring event, the camera was mounted and activated well before the arrival of the release truck and recorded video footage until a minimum of 30 minutes following the truck's departure.

An attempt was also made to collect water velocity information of the channel from near the terminus of the release pipe. An upward facing Acoustic Doppler Velocimeter (ADV) was deployed on the channel bottom near the end of the release pipe. However, during initial testing, it became evident that due to rapid biofouling of the instrument (mostly *Corbula* clams); constant cleaning of the device by a diver would be required to ensure accurate data collection. Due to safety concerns, a diver would not be allowed to clean the ADV, therefore water velocity measurements were not recorded by the upward facing ADV. As an alternative, the ADV instrument was mounted and operated in a downward facing configuration from the side of the research vessel during each sampling effort. This method was also used to collect water velocity data at each of the other monitoring sites. Since the model of ADV (Sontek Argonaut-SW, Sontek/YSI San Diego, CA) used in this study was not manufactured for operation in a downward facing configuration, an effort was made to calibrate and validate the data collected from the device using an alternative method (propeller driven velocimeter). The calibration/validation evaluation demonstrated that accurate measurements could be attained from the ADV in this configuration using an empirically determined data transformation. The ADV adjusted velocity readings correlated well with the propeller probe true velocity readings. If water velocities ranged from 0.3 m/s to 0.6 m/s (0.98 ft/s to 1.97 ft/s), the difference between the propeller and adjusted ADV readings was between 0 m/s to 0.03 m/s (0.0 ft/s to 0.1 ft/s). The methods and results of this evaluation are available in Appendix 11.2. During each monitoring event, water velocity data was collected for 15 minutes following each release. To avoid disturbing fish being observed using the DIDSON, the velocity measurements were not taken until after the camera had been removed, typically 45 minutes after the release.

Figure 23-The fixed mount system being lowered into the water at the SWP Horseshoe Bend release site. Note the DIDSON camera at the end of the mount.

Figure 24-The DIDSON camera mount system in its fully deployed position.

4.1.2 Mobile Monitoring

Mobile DIDSON monitoring was conducted at the two control sites on Horseshoe Bend, the SWP Curtis Landing release site on the San Joaquin River and the CVP Emmaton release site on the Sacramento River. Each site was monitored five times during each monitoring period (the CVP Emmaton release site was only monitored three times during the first monitoring period due to bad weather). Mobile monitoring was conducted from a boat equipped with the side mounted DIDSON camera. The side mount system consisted of a 3 m (10 ft) long pivoting aluminum boom that could be attached to the gunwhale of the boat, with a plate on one end for DIDSON attachment and handle bars on the other end for manual manipulation of the camera orientation (Figures 25 and 26). The design of the mobile monitoring boom allowed the user to rotate laterally 270 degrees and vertically 180 degrees; the boom also included a mechanism to adjust the depth of the camera in order to optimize the DIDSON beam angle on the target to provide the best possible image. To the best of our abilities, the camera was positioned at the same orientation to the target for all mobile monitoring episodes. Once the boat was positioned into place, DIDSON data was recorded for 10 minutes. Water velocity data was concurrently recorded using the same method described for fixed site monitoring. Monitoring at the CVP Emmaton site was limited to observations of the longer of the two release pipes because the shorter of the two pipes is rarely used and because the view of the shorter pipe was obstructed by pilings. Monitoring at the CVP Emmaton and SWP Curtis Landing release sites was conducted during non-release periods.

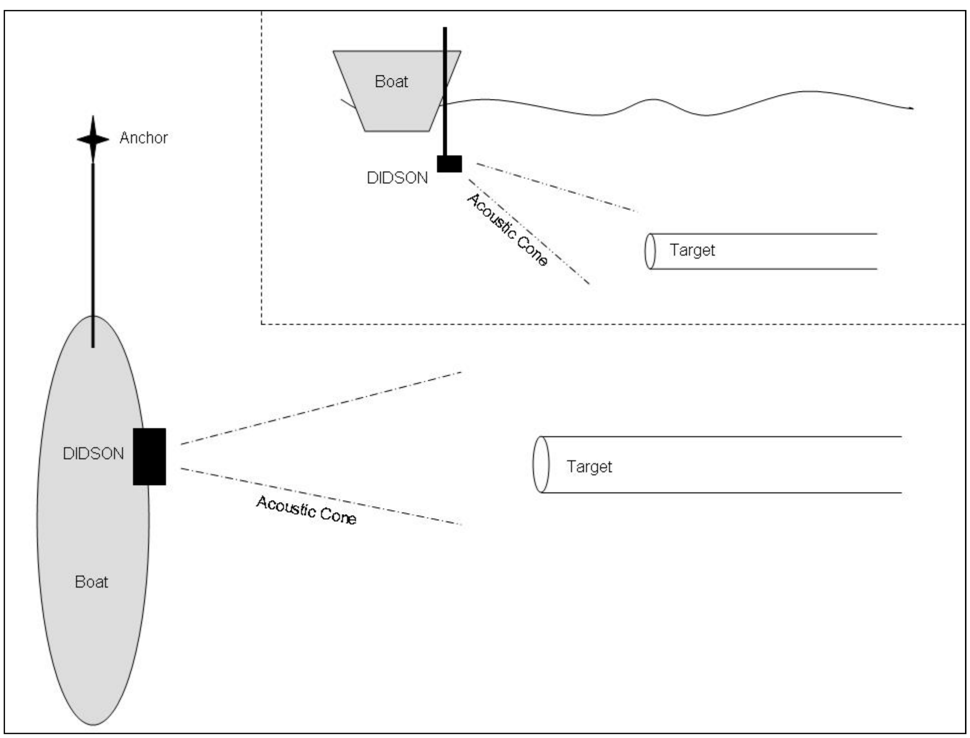


Figure 25- Overhead and side-views of DIDSON mobile monitoring boat positioning.

Figure 26- The DIDSON being used for mobile monitoring. The direction that the camera was pointed could be manipulated using the handle bars shown in the photo.

4.1.3 Side-view Monitoring

Side-view DIDSON monitoring of the SWP Horseshoe Bend release was conducted a limited number of times during monitoring periods two, three, and five. The main purpose of this monitoring was to gain further insight on fish behavior and movement during a release and to examine fish activity near the support structures for the pipe that were not visible from the fixed DIDSON field of view. Side-view monitoring was conducted using the same boat mounted DIDSON system that was used for mobile DIDSON monitoring; however the boat was positioned so that the DIDSON operator could sweep the length of the release pipe from the end of the pipe to near the shoreline. Video footage was collected before, during, and after release as with the fixed footage, however unlike the fixed DIDSON monitoring, only 15 minutes of video before and after release was recorded.

4.1.4 Water Quality

A water quality probe (YSI model 85) calibrated daily, was used to record water temperature (°C), dissolved oxygen (DO, mg/L), and specific conductance (µS/cm) at each of the monitoring sites. Water quality data was recorded during DIDSON observations at each of the mobile monitoring sites and 30 minutes after releases at the SWP Horseshoe Bend release site. Electrical conductivity data was also taken from the Emmaton water quality station in the California Data Exchange Center (CDEC) database. Only conductivity data from the CDEC station was used for analyses since it provided a more comprehensive data set. Water temperature loggers (HOBO® Pro v2 Water Temperature Logger, Onset Computer Corporation, Bourne, MA) were also deployed at each of the monitoring sites for the duration of the study and their data downloaded after the study ended. Only data from the HOBO loggers was used for temperature data analyses because it provided more precise temperature readings due to their placement at the release sites.

4.1.5 Data Analysis

Fixed site DIDSON footage was analyzed post-collection. Video footage from each sampling event was trimmed at 30 minutes before the recorded truck arrival and 30 minutes after the truck departure. The footage was then divided into three segments: pre-release (30 minutes before the truck arrival until 10 minutes before the release), release (10 minutes before release until 10 minutes after truck departure), and post-release (10 minutes after truck departure until 30 minutes after truck departure). During the pre-release segment, a count of all fish visible on the screen was made every five minutes and all notable behavior (feeding, schooling, etc.) was noted. During the release segment, a fish count was made every minute to gather more detailed information about fish behavior during the release. During the post-release segment, fish counts were again made every 5 minutes and all notable behavior was noted.

Mobile monitoring DIDSON footage was analyzed post-collection. The footage was sub- sampled by dividing each 10-minute clip into 30-second intervals. Fish counts were made at the start of each interval, and observations were made of any notable fish behavior or aggregations that occurred within each interval.

All predator counts were converted to an abundance index using the scoring system shown in Table 16 for both fixed and mobile DIDSON monitoring due to difficulty attaining accurate fish counts when more than 50 fish were present in a count. When greater than 50 fish were present on screen, the fish would essentially obstruct each other and could not be differentiated from each other. For comparative purposes, the counts from the “30 minutes prior to release” time period for fixed releases were used for comparison with the mobile sites.

Table 16- Scoring system used to develop a predator abundance index

# of Fish counted	Abundance Score
0	0
1-10	1
11-20	2
21-30	3
31-40	4
41-50	5
>50	6

Given the limited nature of side-view monitoring at the SWP Horseshoe Bend release site, no statistics were performed on this data, nor was it analyzed for enumerable characteristics such as fish abundance. Each clip was analyzed by noting general fish behavior and movement and observing any unusual underwater structure or behavior within the viewable area.

Statistical analyses were performed using SigmaStat 3.5® (Systat Software, Inc., San Jose, CA), SigmaPlot 10.0.1® (Systat Software, Inc., San Jose, CA), and Microsoft Excel® software packages. Descriptive statistics were used to characterize samples. For hypotheses tests, the following procedure was followed: determine if the data met the assumptions of parametric statistical testing procedure including independence of observations, normality, and homogeneity of variance. If the data met these assumptions a parametric hypothesis test was used. If the data did not meet these assumptions the appropriate non-parametric test was used.

4.1.6 Quality Assurance

The YSI model 85 multi-probe was calibrated daily for dissolved oxygen before use using the instrument's calibration routine. No attempt was made to calibrate the meter for temperature or conductivity because data from the CDEC water quality station at Emmaton and from HOBO temperature loggers were used for all data analysis. HOBO temperature logger accuracy was checked before deployment using a glass thermometer.

Water Velocity measurements from the ADV Argonaut were calibrated using the procedure outlined in Appendix 11.2. Raw ADV data was converted to corrected values post collection. Calibrated water velocity data was within 0.03 m/s (0.1 ft/s) at the velocities tested during calibration efforts. Data was checked line by line for errors.

DIDSON counts for all observations were performed independently by a minimum of two trained personnel. Any discrepancy in counts was resolved by two observers viewing the video together and coming to a consensus. All count data was checked line by line for data entry errors.

4.2 Assumptions and Limitations of DIDSON Observations

The DIDSON camera system is a powerful tool for fisheries observations in dark or turbid water. However, there are several assumptions and limitations that are inherent to the system:

1. The DIDSON camera has a limited field of view. During the sampling for this study, typically an area of about 3 m x 4.5 m (10 ft x 15 ft) was viewable. Therefore, significant numbers of predatory fish may have been present outside the field of view of the camera, which may have resulted in under estimations of abundance.
2. The DIDSON camera provides 2-D observations, which might result in large aggregations of fish being underestimated since the fish nearest the camera would obstruct others from view.
3. The footage from the DIDSON camera is not clear enough to allow species identification. All fish counted from video footage were assumed to be piscivorous species. However, results from the electro-shocking aspect of the study showed that several non-piscivorous species including Sacramento blackfish, Sacramento sucker, splittail, and hitch were located within the study area.
4. The DIDSON could not be operated during nighttime releases or during severe weather conditions due to safety reasons. Predator behavior and abundance could potentially be different during these periods.

4.3 Results and Discussion

4.3.1 Overall Predator Abundance

A one-way ANOVA analysis showed that predator abundance based on DIDSON estimates was significantly higher ($p<0.001$, $n=24$) at the SWP Horseshoe Bend release site in comparison with the control sites during all monitoring periods except monitoring period 4 (February, $p=0.152$) when abundance was low at all the sampling sites. The SWP Curtis Landing release site and CVP Emmaton release site also had significantly higher predator abundance during the second (CL $p=0.003$, Emm $p=0.017$) and third (CL $p=0.014$, Emm $p<0.001$) monitoring periods. Both control sites had consistently low predator abundance. No greater than 7 fish were ever observed at either control site at any one time. Typically no fish were observed at the control sites (Figure 27).

Although near-field predator abundance at the release sites does appear to be high, our observations suggest that this is a seasonal occurrence. Figures 28 and 29 illustrate the greatest predator abundance occurring during the summer and early fall, tapering off into the winter and increasing again in the early spring. Hydroacoustic data discussed in the next section reveals that this is in fact a near field phenomenon and that predator abundance in the open waters of the study area actually revealed the opposite pattern. This difference in near field abundance and far field abundance suggests that the release is in fact an attractant, more so than simply the release site structure itself.

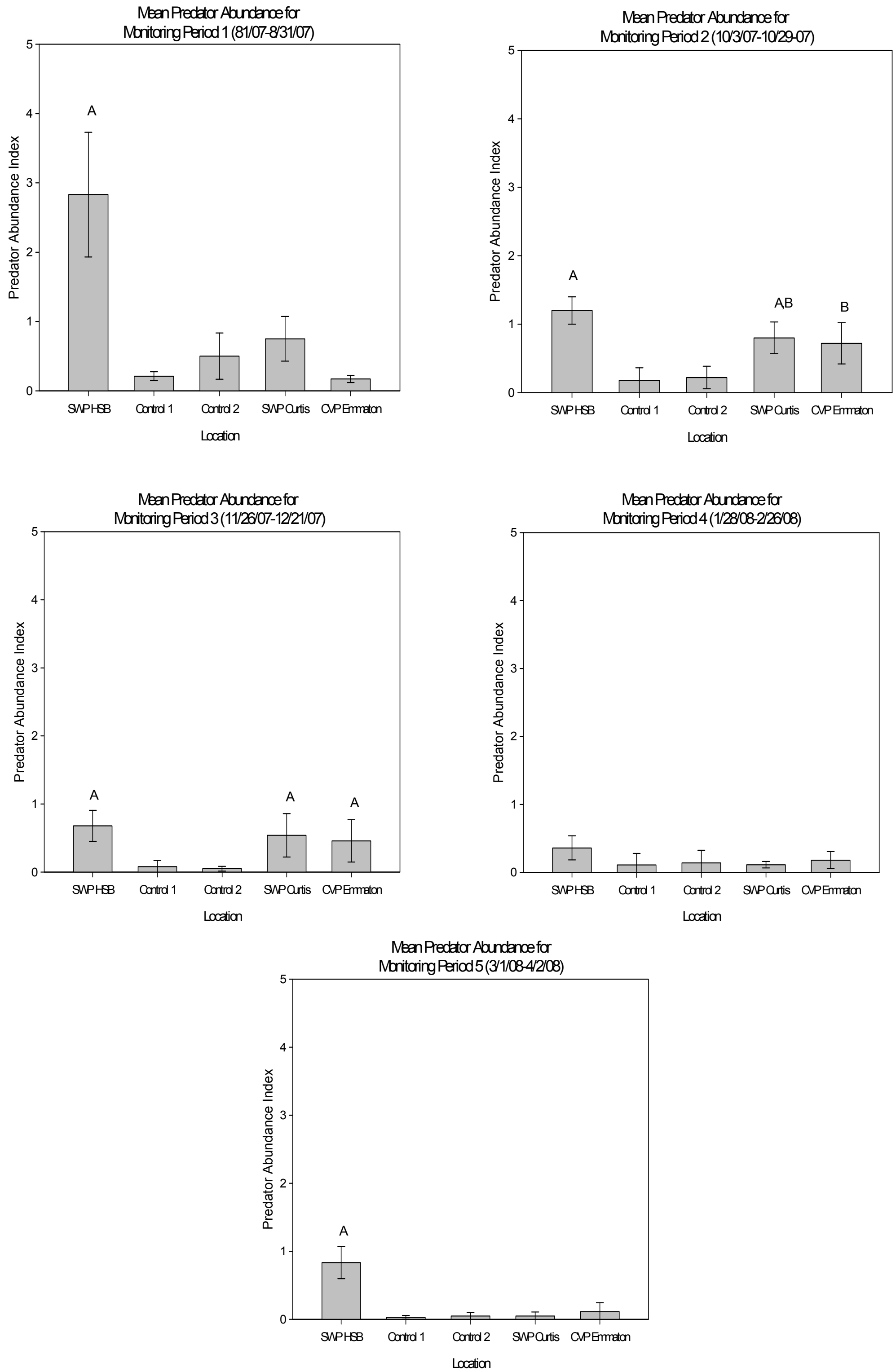


Figure 27- Mean predatory fish abundances during each of the five monitoring periods. Statistically significant groups are denoted by letters.

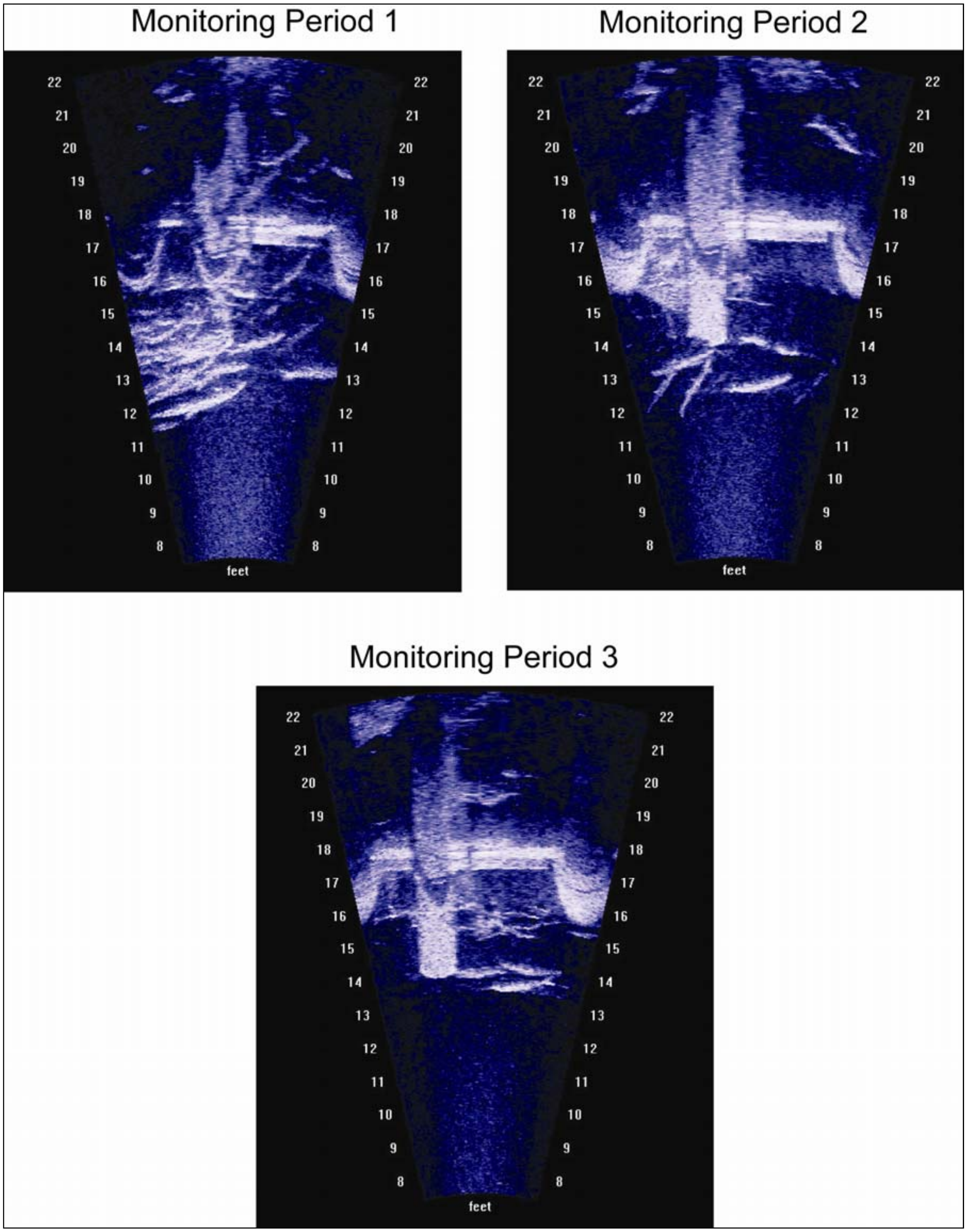


Figure 28- Typical DIDSON views of pre-release activity at the SWP Horseshoe Bend release site for monitoring periods 1-3. Note the large aggregation of fish during monitoring period 1 obstructing the release pipe.

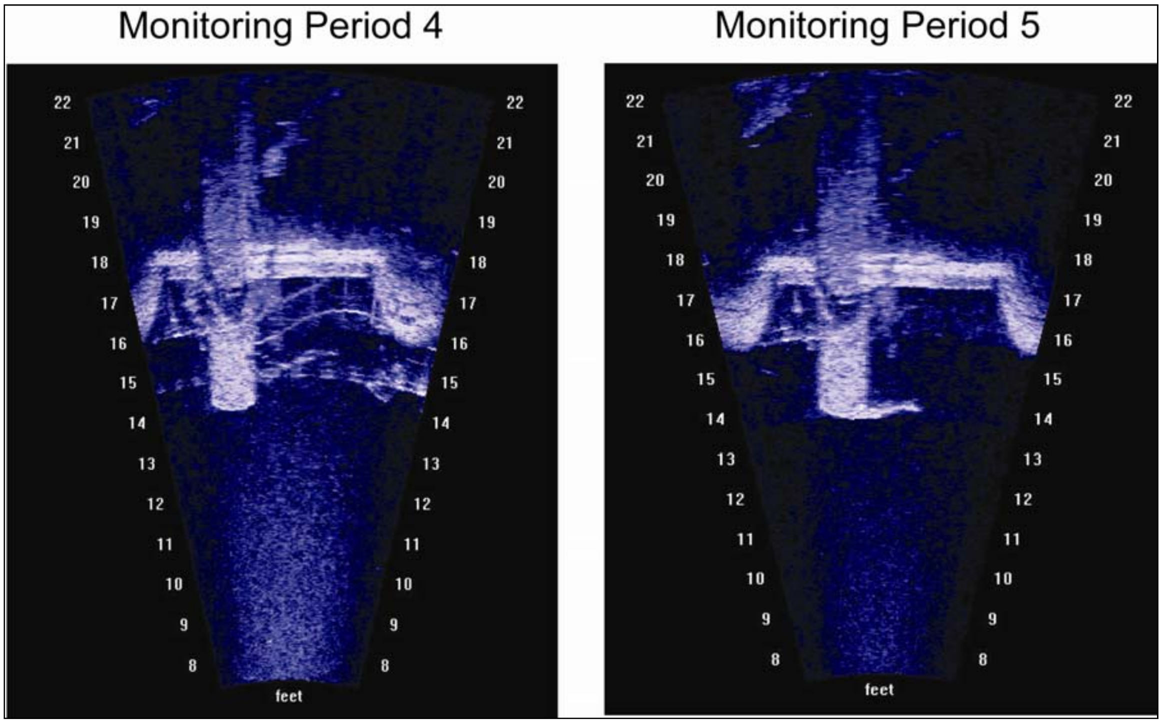


Figure 29- Typical DIDSON views of pre-release activity at the SWP Horseshoe Bend release site for monitoring periods 4-5. Note the absence of fish during the 4th monitoring period.

4.3.2 SWP Horseshoe Bend Release Site

4.3.2.1 Predator Abundance in Response to Numbers of Salvaged Fish

A Pearson Product Moment Correlation test ($R=0.808$, $p<0.001$, $n=23$) and a Regression analysis ($R^2=0.652$, $n=23$) showed that the number of fish salvaged at the SDFPF was correlated with predator abundance at the SWP Horseshoe Bend release site (Figure 30). The strong positive correlation indicated that as the number of fish salvaged increases, the number of predators holding within the immediate vicinity of the release pipe also increases.

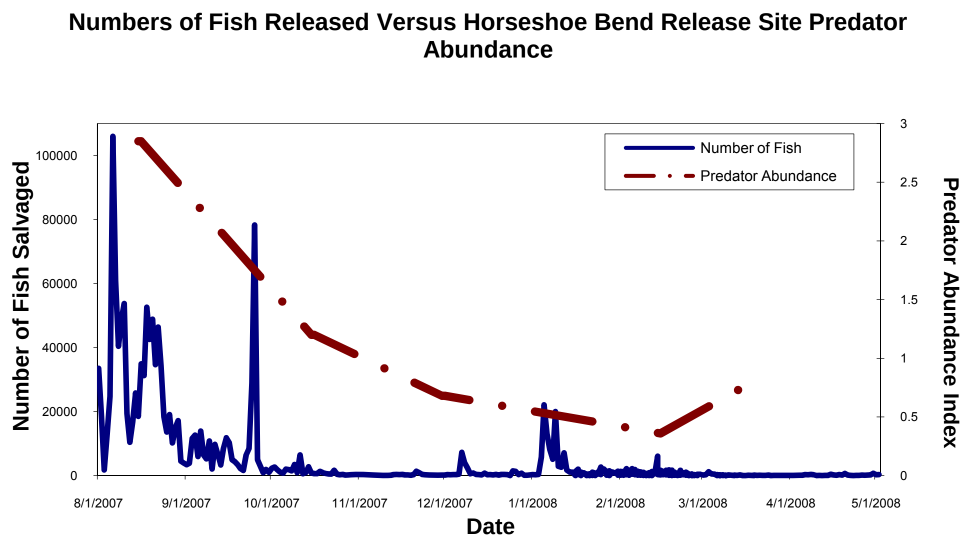


Figure 30- Relationship between the number of SWP fish salvaged and released and SWP Horseshoe Bend release site predator abundance. Salvage from 8/1/07 to 10/1/07 consisted largely of threadfin shad, while the small peak in salvage in mid-January 2008 was a combination of striped bass, American shad, and yellowfin goby.

4.3.2.2 Behavior During Releases

During all DIDSON monitoring when fish were present, predatory fish at the SWP Horseshoe Bend release pipe were characterized by similar behavior. Prior to release, several fish would typically line up near the end of the release pipe positively rheotaxic to the flow of the channel (Figure 31). Many fish also appeared to swim amongst the piles and support structure, intermittently orienting to the flow when large numbers of predators were present (monitoring periods 1 and 2). For 1–2 minutes before the release, the fish would become agitated and dart around quickly, presumably in response to operation of the release facilities (corrugated pipe connection, flushing pump activation, etc), though this behavior was inconsistent and lasted for only a few seconds. As the release occurred, a white plume was visible in the DIDSON image, which was most likely caused by entrainment of air bubbles in the water exiting the release pipe (Figure 32). This plume made close observation and quantification of strikes by predators difficult, but the predators were clearly feeding on prey coming out of the pipe.

During periods when predatory fish abundance was highest (monitoring periods 1 and 2) predatory fish were typically seen forming a large aggregation at the end of the pipe with predatory fish darting in and out of the center of the aggregation, presumably feeding. Occasionally, salvaged fish could also be seen successfully escaping (within the DIDSON's field of view) and swimming away from the pipe. Interestingly, predators were rarely seen chasing these fish, but rather stayed aggregated at the immediate end of the pipe. During periods of low predator abundance, salvaged fish could usually be seen swimming out of the plume/pipe and swimming away from the area.

Once the release was completed, predator abundance at the end of the pipe remained elevated at least up until the time the DIDSON was removed and observations were stopped (typically 45 minutes to 1 hour post-release). This extended elevation in predatory fish abundance suggests that predators attracted to a release may stay at or near the release site for extended periods of time following releases. A notable observation in many releases was that salvaged fish appeared to exit from the pipe for an extended period after the release was over. This observation suggests that at least some fish became trapped or delayed within the pipe. This observation is further supported by pilot efforts to examine the release pipe after a release using an underwater camera. During these pilot efforts, video footage was recorded showing trapped fish and debris in the pipe long after a release. Additionally, the results of the Element 3 study showed that significant debris and potentially salvaged fish remain in the pipe after release, due to the lack of a sufficient flushing flow in the release pipe.

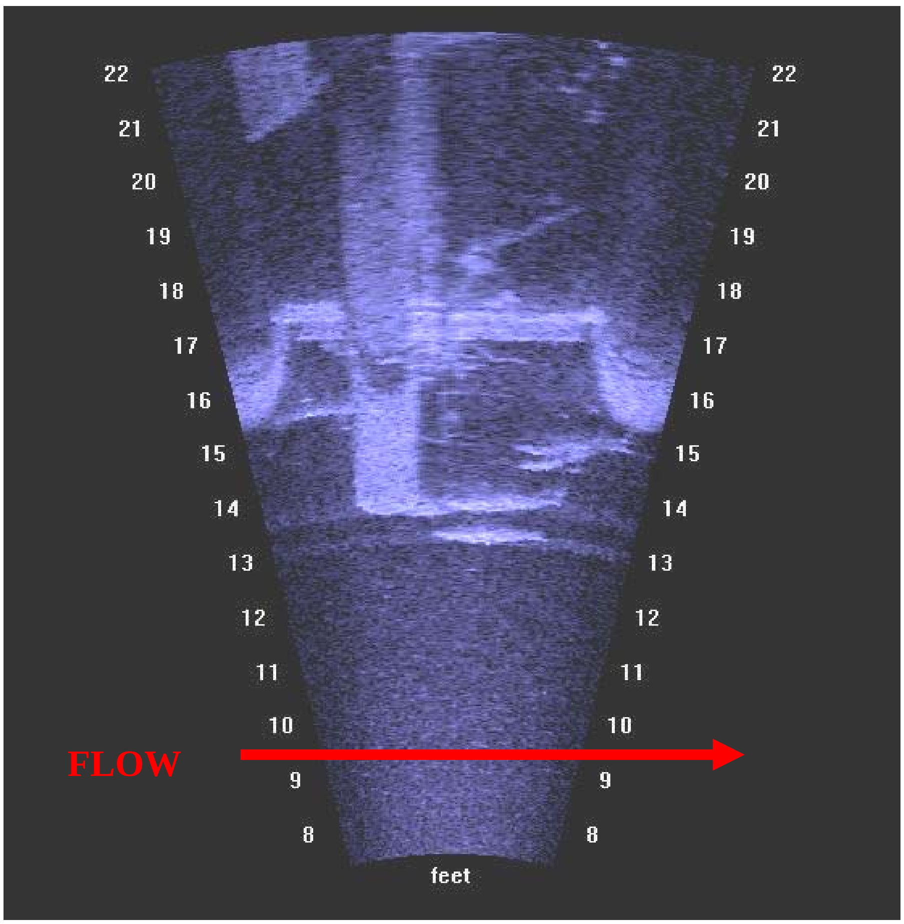


Figure 31- Typical view of predator behavior before releases. The predators in this image are oriented into the flow, holding near the end of the pipe.

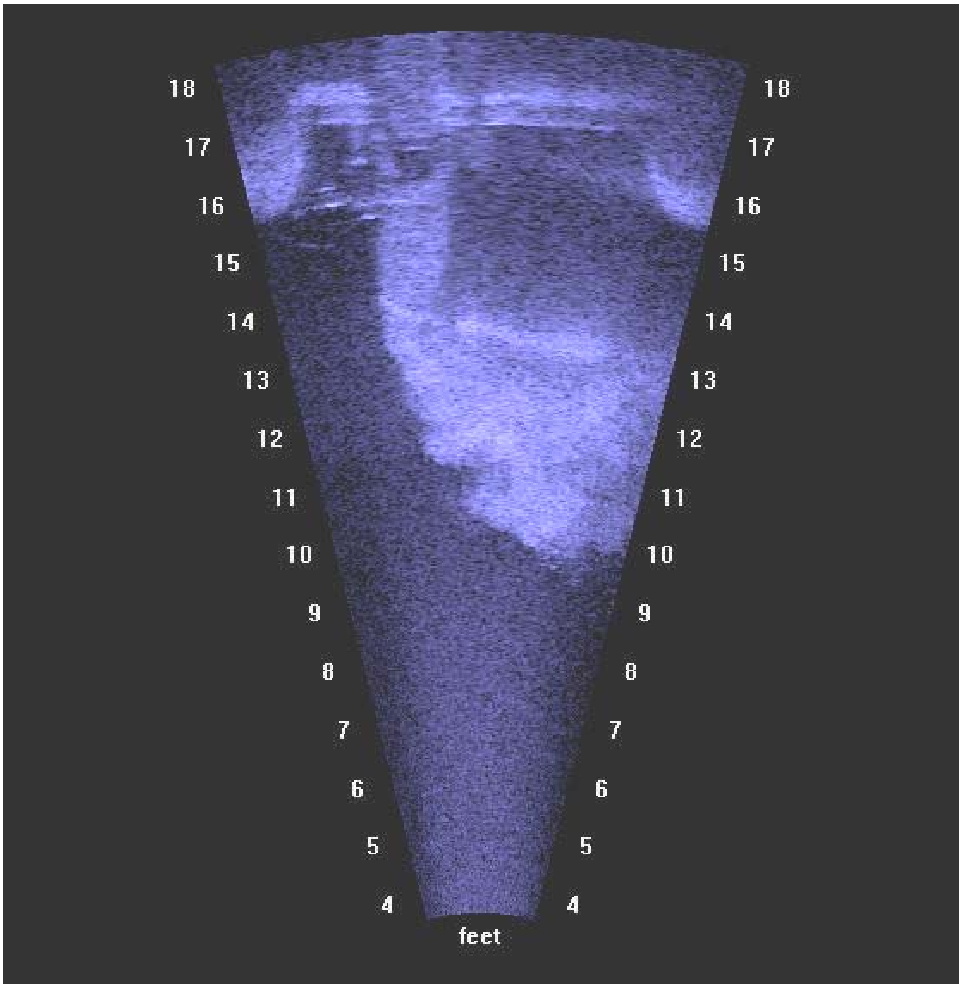


Figure 32- DIDSON image captured during a release. Note the plume extending out from the release pipe. The plume was presumably caused by bubbles entrained in the water being released and often obscured observations of release activity.

4.3.2.3 Response to Release Events

Predator response to individual release events including the release truck arrival, corrugated pipe connection, and flushing system activation was inconsistent. During monitoring periods 1 and 2 when elevated numbers of fish were present,, no correlation between release truck arrival (R_S = 0.064; n = 10; p = 0.700) or flushing pump activation (R_S = 0.088; n = 10; p = 0.454) and fish abundance during the corresponding time period was detected using a Spearman Rank Order Correlation Analysis (corrugated pipe connection time was not recorded during monitoring periods 1 or 2). During some sampling events, fish near the end of the pipe did appear to become agitated and dart away rapidly, but this occurred intermittently and lasted for only a few seconds each time. Predator abundance also remained relatively constant up until the time of release.

4.3.3 Predator Abundance and Behavior at Mobile Monitoring Sites

4.3.3.1 Abundance

As shown in Figure 27, predatory fish abundance at the release sites was generally comparable during three of the monitoring periods, but significantly higher at SWP Horseshoe Bend during the first (August) and last (March/April) monitoring periods versus all other sites. The reason for this disparity is unknown, but may be a result of several factors. At the SWP Curtis Landing release site, there is much less pipe support structure as a result of the channel bathymetry and height of the levee. At this site, the channel quickly drops off to a deep depth (~4 m [13 ft]) within only a short distance(<2 m [6.5 ft]) from shore (steeper pipe slope). The result is that the site design required much less pipe to reach an appropriate depth according to the original design requirements (recommended depth of 6 m, DFG unpublished document). Additionally, the levee at this location is roughly half as tall as at the SWP Horseshoe Bend release site, further minimizing the amount of pipe support structure required to achieve the desired depth of the pipe outlet, per the original design requirements. This lack of support structure eliminates the problem of debris being trapped that was observed at the SWP Horseshoe Bend release site.

At the CVP Emmaton release site the reduced number of predators cannot be attributed to the lack of pipe support structure as at the SWP Curtis Landing release site. The extensive pipe support structure and catwalk out to the water quality station are clearly visible in Figure 7. At this site, the decreased number of predators as compared to the SWP Horseshoe Bend release site might be attributed to several different factors. First, the CVP release sites include a higher output flushing system that operates on a timer. The greater amount of flushing water may result in fewer salvaged fish being trapped in the pipe. Additionally, the timer on the flushing system randomly turns the flushing flow on four times per day, potentially desensitizing predatory fish to the release site. Another reason for lower predator abundance may be that the depth at the outlet of the longer of the release pipes is ~2 m (6.5 ft) deeper than at the SWP Horseshoe Bend release site. This difference in depth might result in a different species composition shifted away from littoral species to more pelagic species that might not associate as strongly with structure. The difference in depth might also result in different hydraulics that might make the site more energetically costly to maintain position at in comparison to the Horseshoe Bend site. The ADV Argonaut velocimeter used in this study has a range limitation of five meters, as a result the CVP Emmaton site might not have been effectively sampled since depths at this site were typically >6 meters (20 ft) even at the lowest river stages. Similarly, since the CVP Emmaton release site is located at the confluence of Horseshoe Bend and the mainstem Sacramento River, as the two channels come together they might create additional complex hydraulic forces as was evident from the debris lines and water movement patterns observed during data collection.

Predators were rarely observed at the control sites throughout the study. This suggests that the salvaged fish releases at the release sites were the principal attractants of predators as opposed to some other factor such as the presence of a man-made structure. In fact Control Site 1 had some of the most complex underwater structure of any of the sites sampled, consisting of a series of pipes, piles, and two large cylindrical fish screens, yet there were few predators observed.

4.3.3.2 Behavior

Predator behavior at the CVP Emmaton and SWP Curtis Landing release sites was similar to that observed at the SWP Horseshoe Bend release site. Predators could typically be observed oriented into the flow of the channel near the outlet of the release pipe. At the SWP Curtis Landing, unlike at the SWP Horseshoe Bend release site, predators were not observed using the length of the pipe between the outlet and the shoreline as cover but instead were aggregated loosely near the pipe outlet. This is, as stated earlier, most likely a result of the decreased complexity of habitat and cover caused by the different release site design.

At the CVP Emmaton release site, predator behavior was difficult to observe because the DIDSON was at the limit of its range due to the depth of the site and because the DIDSON’s view was obstructed by the pilings and support structure. However, predators could be seen milling near the outlet of the release pipe and orienting into the flow of the channel.

While few predators were observed in general at the control sites, there were some notable differences in their behavior as compared to release site predators. The majority of observations at the control sites were of predatory fish simply swimming past or through the site and not holding position. On occasion some fish were observed holding position at the control sites, but it was usually solitary fish rather than aggregations of fish seen at the release sites.

4.3.4 Response to Environmental Parameters

4.3.4.1 Water Velocity

Mean water velocity at each of the study sites was lowest at the SWP Horseshoe Bend release site (Table 17). However, due to the limited number of sampling events during each monitoring period, there was insufficient data to perform any meaningful analyses of predator abundance in response to water velocity. Typically during any one monitoring period, only a small range of water velocities were observed; therefore there was no opportunity to examine predator behavior and abundance in response to different water velocities during an individual monitoring period. It is of interest to note, however, that mean water velocity at all sites was highest during the fourth and fifth monitoring periods when predator abundance was generally low for all sites (Table 18). Given the tidal nature of this area, however, the daily fluctuations in water velocity would seem to negate any meaningful influence of water velocity on predatory fish holding behavior at the release site. Regardless of what the daily peak water velocity at a given release site is, at some point over a tidal cycle, the water velocity will decrease to the point that it will not have an energetic cost for predatory fishes. Both striped bass and Sacramento pikeminnow are common in the upper Sacramento River where typical water velocities are several times greater than in the Delta. Therefore, the highest water velocities possible at the release sites would be well below the swimming performance capabilities of the larger predatory fish present at the release sites.

Table 17-Mean, maximum, and minimum Delta water velocities observed at each of the survey sites.

Location	Mean Water Velocity (ft/s)	Maximum Water Velocity (ft/s)	Minimum Water Velocity (ft/s)
SWP HSB	0.620	1.369	0.083
SWP Curtis Landing	0.843	1.978	0.007
CVP Emmaton	0.889	1.766	0.133
Control 1	0.873	1.890	0.085
Control 2	0.937	1.422	0.095

Table 18- Mean water velocities ± SE (ft/s) during each monitoring period for each of the 5 survey sites.

	Location				
Monitoring Period	SWP HSB	SWP Curtis Landing	CVP Emmaton	Control 1	Control 2
1	0.393 ± 0.132	0.661 ± 0.209	0.975 ± 0.060	0.980 ± 0.239	0.671 ± 0.155
2	0.435 ± 0.120	0.734 ± 0.355	0.653 ± 0.214	0.550 ± 0.166	0.728 ± 0.236
3	0.385 ± 0.132	0.555 ± 0.249	0.566 ± 0.135	0.897 ± 0.227	0.934 ± 0.284
4	0.886 ± 0.192	0.907 ± 0.226	1.186 ± 0.290	0.886 ± 0.282	1.190 ± 0.052
5	0.993 ± 0.133	1.312 ± 0.160	1.238 ± 0.227	1.054 ± 0.317	1.161 ± 0.086

4.3.4.2 Temperature

Water temperature at the SWP Horseshoe Bend Release site was tested for correlation with predator abundance at the SWP Horseshoe Bend release site. A Pearson Product Moment Correlation test ($R=0.819$, $P<0.001$, $n=23$) and a Regression analysis ($R^2=0.681$, $n=23$) showed that temperature and predator abundance were positively correlated (Figure 33). This trend of decreased predator abundance correlated with decreased temperature is not unexpected and is likely a result of the decreased need of the predators to feed when water temperatures are colder as a result of their decreased metabolic demand (Brett and Groves 1979). Interestingly this trend was not observed with hydroacoustic data, and in fact the opposite trend was observed with increased numbers of predators in the area during the winter months observed with the hydroacoustic equipment. This may be a result of the different ranges and coverage areas inherent to each technique. While the DIDSON was able to capture predators holding tightly to the release pipe/site, the hydroacoustics had a longer range and effectively sampled the open water areas surrounding the release sites. The predators observed using the DIDSON were more than likely fish that were actively feeding or searching for prey, thus their attraction to the release site, whereas the hydroacoustics was able to show seasonal differences in striped bass abundance in the area, but not necessarily feeding because the water temperatures were low.

Temperature may have also had an effect on the populations of prey fish in the open water areas surrounding the release site. If prey densities in the area were substantial, while concurrently the number of fish released decreases, it may be that the release sites no longer represent a better feeding opportunity.

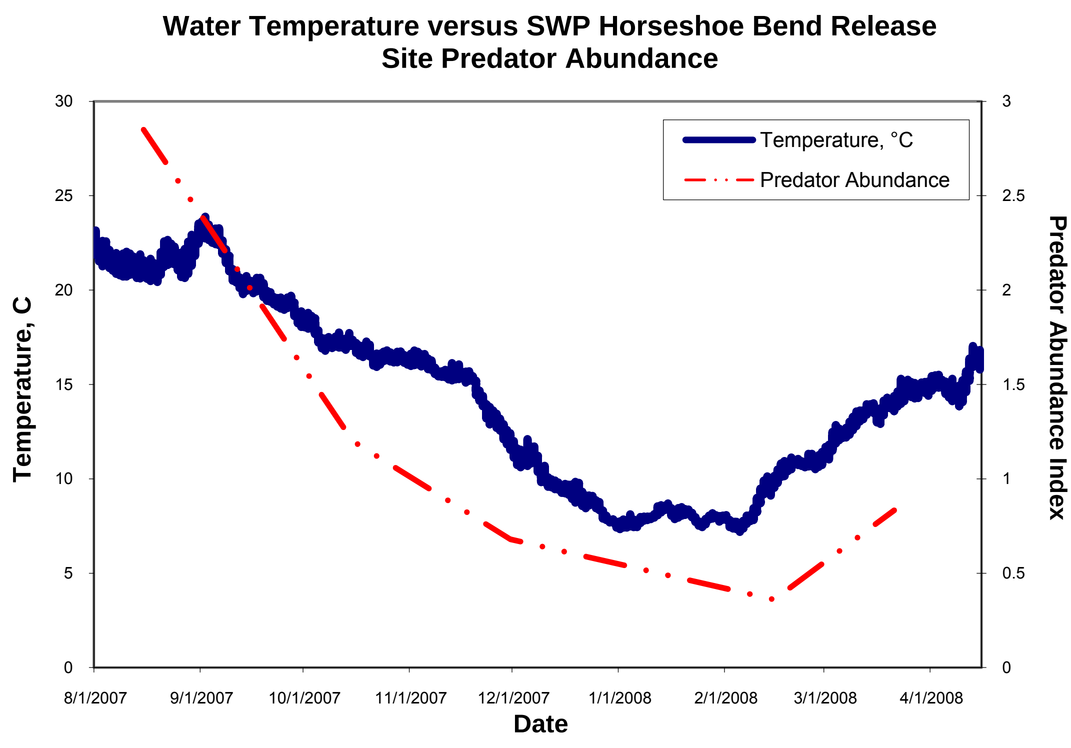


Figure 33- Relationship between water temperature during the study and mean predator abundance at the SWP Horseshoe Bend release site. Water temperature at all other sites was within 1ºC.

4.3.4.3 Electrical Conductivity

Electrical conductivity at Emmaton (monitoring station is located at CVP Emmaton release site) was generally lowest during the fourth and fifth monitoring periods (min= 167.91 µS/cm on 2/1/2008) and highest during the second and third monitoring periods (max=2889.79 µS/cm on 12/7/2007). This coincides with the periods of typically the highest and lowest net Delta outflow.

SWP Horseshoe Bend release site predator abundance was tested for correlation with daily average electrical conductivity at Emmaton. A Pearson Product Moment Correlation analysis showed no significant relationship between electrical conductivity and predator abundance ($R=-0.119$, $n=23$, $p=0.587$). This suggests that at this location and within the range of conductivity values observed, electrical conductivity is not a limiting factor for any of the predator species observed.

4.3.4.4 Dissolved Oxygen

Dissolved Oxygen remained relatively high and relatively constant for the duration of the study (min=7.23 mg/L on10/5/2007, max=10.68 mg/L on 2/15/2008). A Pearson Product Moment Correlation test with Dissolved Oxygen and predator abundance showed no significant relationship ($R=-0.316$, $n=22$, $p=0.152$). This is not unexpected since the Dissolved Oxygen values observed were well above the minimum requirements of the principal predatory species in the area.

4.3.5 Sideview Monitoring

Sideview monitoring was conducted three times during the first monitoring period, once during the third monitoring period, and twice during the fifth monitoring period. Statistical examination of sideview DIDSON footage was not performed due to the limited number of samples, so a more descriptive approach to the observations was employed. The limited footage collected was instrumental in examining how the geographic distribution of predators at the release site changed during a release and in examining habitat utilization in the vicinity of the SWP Horseshoe Bend release pipe. While the fixed mounted viewing angle provided imagery of only a small area near the end of the pipe, sideview monitoring allowed the entire submerged length of release pipe and the surrounding area to be examined. During all sampling except during the 5th monitoring period, when few or no fish were present, most fish were observed not swimming very far beyond the end of the pipe towards the center of the river channel. At times during the second monitoring period, >50 fish could be observed swimming near the pipe, but very few were observed only a few feet out (<1.5 m [5 ft]) from the end of the pipe. Most of the fish appeared to be either lined up at the end of the pipe positively rheotaxic to the channel flow, or aggregating tightly amongst the piles and pipe support structure closer to the shoreline. Sideview monitoring revealed that the pipe support structure and piling captured/trapped a large amount of debris (branches and logs); (Figure 34).

As the release was conducted, the geographic distribution of predators at the release site changed rapidly. As described earlier, predators were seen aggregating at the end of the release pipe. However, during several observations, predators were observed swimming in and out from the debris trapped along the length of the pipe, often swimming towards the end of the pipe to feed. The presence of this trapped debris effectively negates one of the principal reasons that the pipe was designed with such a long length: to release fish away from the litoral zone where they may be subject to predation by a wider variety of predators. This is especially concerning as the electroshocking data showed that largemouth bass and other centrarchids were very abundant in the vicinity of the release site. Largemouth bass and many other centrarchids are commonly known to associate strongly with any sort of structure. Periodic removal of this debris might therefore, reduce release site predation associated with predators utilizing this trapped debris as refuge.

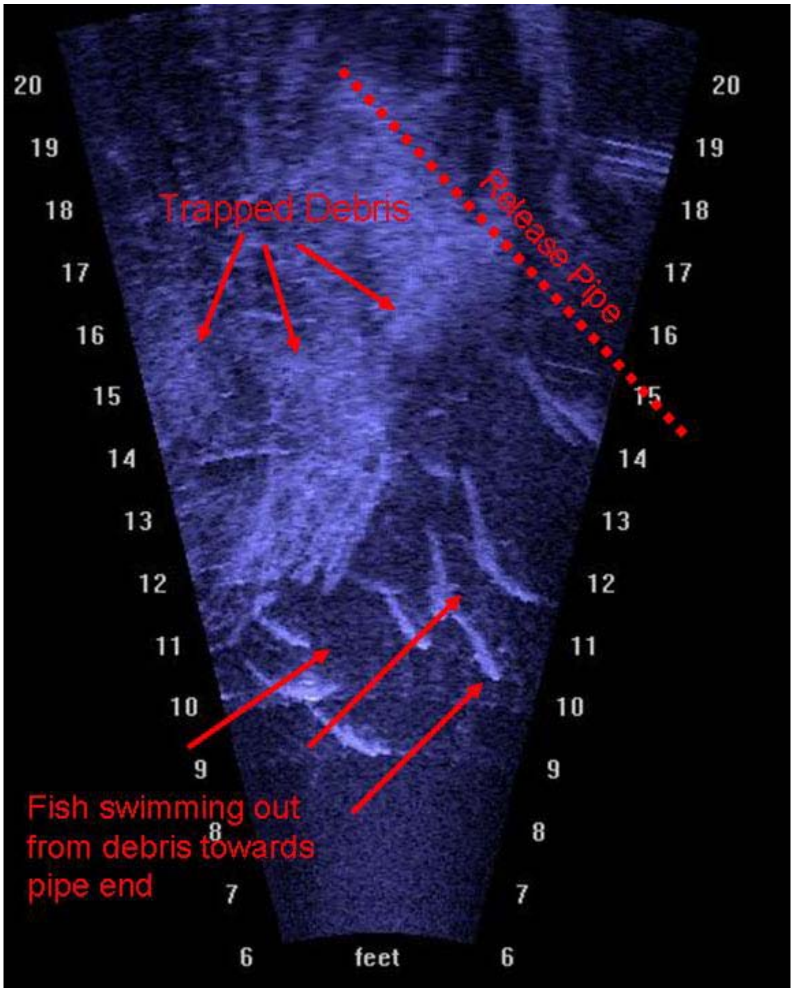


Figure 34- Sideview DIDSON image of predators swimming amongst submerged debris trapped by the release pipe support structure.

4.4 Conclusions

The results of the DIDSON monitoring showed that predatory fish abundance at the SWP Horseshoe Bend release site was generally highest when greater numbers of salvaged fish were being released. However, this was in contrast to the results of the hydroacoustics monitoring, discussed in the next section, which showed the opposite trend. This difference probably is a result of the differing ranges for the equipment (longer range for hydroacoustics, shorter for DIDSON), but also demonstrates the differing magnitude of attraction of predatory fish to the release site during different seasons or operational conditions. During seasons when many fish were being consistently released, many predators were observed aggregating very close to the release pipe even though the hydroacoustics showed there were generally fewer predators in the region during these seasons. Similarly, when very few fish were being released, very few predators were observed near the release site in contrast with the large regional population of predators observed with the hydroacoustics equipment.

Observations with the DIDSON camera failed to reveal any aspects of the release process that might be serving as behavioral attractants (i.e. pump activation, truck arrival). Rather, the driving reason for predators remaining at the release site appeared to be the delayed rate at which many salvaged fish exited the release pipe. Salvaged fish were observed slowly trickling out of the pipe over many hours. This constant source of food might continually attract predators to the site.

Observations with the DIDSON camera also revealed inherent problems with the existing release site design. The observations showed that the underwater structure of the release sites trapped excessive amounts of debris within the immediate vicinity of the release pipes that appeared to serve as predatory fish cover or habitat. To reduce this problem, the debris around the release sites should be periodically removed, and future release site designs should minimize the potential for entrapment of underwater debris by incorporating less pipe support structure.

5.0 Hydroacoustics and Bioenergetics

The objectives of this study component were to further describe the behavior of predators near the SWP Horseshoe Bend release site, and to attempt to quantify the potential magnitude of predation. This study component employed a two tiered approach of both fixed station acoustics and mobile surveys for collecting acoustic data. Fixed station data was used to describe behavioral aspects of potential predators in the immediate vicinity of the release pipes as defined by the effective sampling range of the transducers. Population level estimates of potential predatory fish were determined using mobile acoustic surveys of Horseshoe Bend. The potential magnitude of predation was determined using a simple bioenergetics approach of computing consumption based on water temperature and growth rates of predatory fish species known to be present in the area.

5.1 Methods

The hydroacoustics part of the study focused on the Horseshoe Bend region of the study area. Since hydroacoustics cannot be used to speciate the fish observed, data collected from electro-shocking surveys, DIDSON observations, and the literature was used to determine which species were likely present near the release site.

5.1.1 Data Collection

5.1.1.1 Fixed Site

The fixed site refers to those transducers affixed near the outlet of the release pipe at the SWP Horseshoe Bend release site. These units were used to examine behavior of fishes in the local vicinity of the release pipe. In this case it represented a semi-circular area approximately 25 m (82 ft) in radius (Figure 35). In the initial proposal one acoustic unit was to be placed away from the release pipe looking towards the pipe, however, because of DWR restrictions on diving activities, the units could not be deployed to directly look at the release pipe. Funding constraints prevented use of a similar fixed station at a control site but DIDSON Camera operations at those sites yielded sufficient data for a comparison.

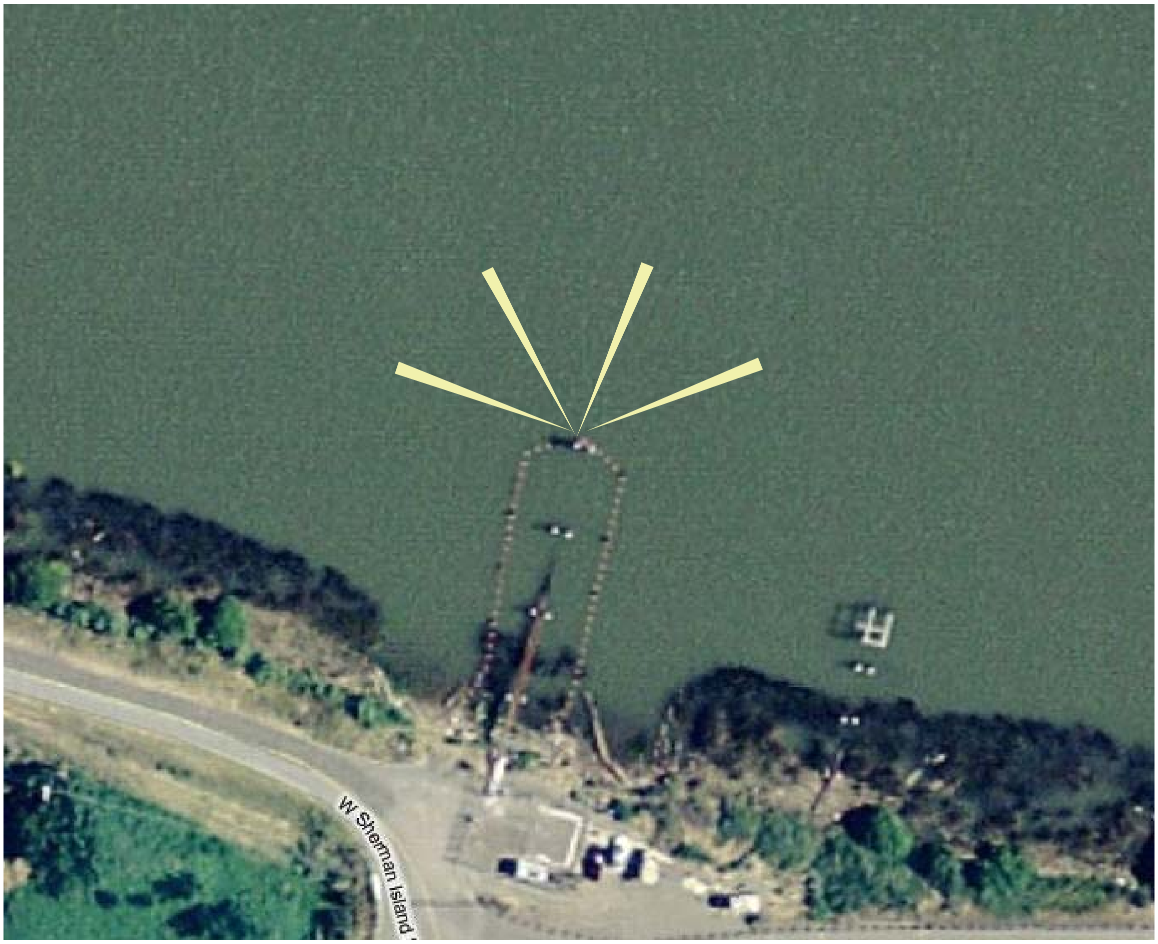


Figure 35- Location of four transducer beams as they sample near the outlet pipe location. Beams and beam spreads are approximately to scale, with a range of 25 m (82 ft) and a beam angle of 6.5°.

To maximize the amount of data collected, a fan shaped array of four transducers mounted to a semi-circular metal plate which could be raised and lowered to a given depth was employed (Figure 36). This plate was mounted to a 2.5 inch (6.35 cm) standard conduit slid through a metal collar attached just above the waterline of the most outboard support piling for the release pipe. Bolts attached to the collar held the array fixed in position. By releasing several bolts the pipe could then be lowered to the approximate depth of the release pipe. At the end of each study period the array was removed from the water to prevent accidental damage or vandalism. Large amounts of fishing line primarily from shore anglers was hung up around the piling, and it had to be cut loose every time the array was deployed.

Figure 36- The four-transducer assembly used for this study. The knobs on the mounting brackets could loosen to allow assembly to be raised and lowered. The transducer on the left points almost directly in front of the release pipe. This picture was taken before attaching shore cables to each transducer.

The acoustics units employed for fixed station work were a pair of Biosonics® DT6000 split-beam systems (Biosonics, Inc., Seattle, WA), each connected to two transducers, one 420 khz, the other 200 khz. Transducers were alternated on the array (420,200,420 200) to prevent cross talk between similar frequency transducers. During the first placement, HPR (Heading, Pitch, and Roll) sensors were used in two of the transducers to orient them. Subsequent damage to the underwater cables, likely from stress breaks due to debris and fishing line, resulted in contact with the sensors being lost. This was not an issue following the first deployment as the pole had been marked to allow replicate placement of the equipment each trip.

A pair of surface control units (Biosonics DT 6000) were placed in a climate controlled utility trailer located within the fenced enclosure of the release site. Each unit operated two of the transducers. Connection to the transducers was provided through four, 152–m (500–ft) cables, run through a PVC conduit down to the water line then hung free in the water out to the transducers. Pentium Class laptop computers were connected to each surface unit and used to record data, via Biosonics Visual Acquisition Version 4 (Biosonics, Inc., Seattle, WA). Data was downloaded to a back up hard drive following the completion of each sampling trip. There was on site power provided to the trailer, which was channeled through a battery backup to ensure continued operation during intermittent power failures. When operating, data was collected at a rate of 5 pings/sec, pulse width was set to 0.4 ms, and the data collection threshold at -70dB. Maximum sampling range was typically set to about 40 m (131 ft), but during analysis much of the long range data was removed, because of debris issues (logs etc. stuck near the pilings that blocked the transducer image. Final analysis ranges for the fixed site data were set to 20 m (65.6 ft) for the two HPR transducers and 25 m (82 ft) for the two non-HPR transducers. Each unit was operated 24 hrs a day for the duration of the study period, typically ten days.

5.1.1.2 Mobile Survey

Mobile survey data was used to determine density differences in potential predatory fish populations between the release site and two reference sites located further upstream in Horseshoe Bend (Figure 37). A boat was equipped with an AC inverter to provide electrical power for the computer and surface unit. When conducting surveys the boat was kept at a constant speed of about 7.2 km/hour (4.5 mph). Mobile survey data was collected using the same type of acoustic equipment used for fixed surveys. The only exception was the unit employed 2-200 khz transducers. The surface unit was also a Biosonics DT6000. One transducer was mounted looking vertically down into the water column, the other mounted to aim laterally off to the side. When collecting data the unit was set at 5 pings/sec, 0.4 ms pulse with a data threshold of -70 dB. Maximum range for the downward looking unit was set to 15 m (50 ft), and 40 m (131 ft) for the side oriented transducer. A WAAS enabled E-Trex Vista™ (Garmin International, Inc., Olathe, KS) GPS unit was connected to the surface unit and a location recorded for each target.

Figure 37- A typical set of transects during mobile surveys. August 2007 is shown as an example. The SWP Horseshoe Bend release site is the lower left set of transects, while the other two sets of transects are the two control sites.

A central point was selected for each control site and transects extended 0.4 km (0.25 mi) upstream and downstream of this point (Figure 37). At the release site the survey was extended 0.4 km (0.25 mi) upstream and downstream of the outlet. Transects were run parallel to the flow of the river, with five transects of data collected at each site every sampling period. Moving into or with the wind resulted in the least amount of impact imparted due to wave action. When moving perpendicular to the waves, i.e. across the channel, rocking of the boat made acoustic data analysis difficult, as the unit alternated between looking skyward, then into the river bottom. Wind was only an issue in August. As the season progressed winds died down, and conditions were relatively calm for the majority of the sampling days.

During each sampling period efforts were made to obtain at least 4–5 days of mobile transects. Winds, and occasional periods of heavy rain were the limiting factors as to how often data could be collected. Both wind and rain significantly degrade the quality of collected data, effectively making analysis impossible. Each sample day typically consisted of an afternoon sampling period, then re-sampling all three sites after dark. The order the sites were sampled changed each time. If Control Site 2 was sampled first one trip, the SWP Horseshoe Bend release site was sampled first the next trip. Control Site 1 was always sampled second as it was the middle site. One complete set of transects for all three sites typically took about 2 hours.

5.1.2 Data Analysis

Echo counting methods were used to measure acoustic target strength (fish size) and direction of movement. Target strengths were measured using split-beam analysis techniques for all sample locations. The target strength of a fish is generally related to the size of the fish, and is a measure of the capacity of a fish to reflect sound energy. Target strength, measured in units of decibels (dB), is calculated from the energy reflected from the target, and is a function of the cross-sectional area of the target and the density difference between water and the component parts of the target (bones, scales, flesh, gas bladder and others).

Fish orientation, and to an extent species, can play a significant role in estimation of target size. The decibel scale used to measure fish size is logarithmic and referenced in negative numbers where the larger the negative number, the smaller the fish. For example, a small, -56 dB fish varies in length from 2.7 to 2.8 cm (1.06 to 1.1 in) and a larger -46 dB fish varies from 8.9 to 9.2 cm (3.5 to 3.6 in) length; a -36 dB fish is approximately 25 cm (9.8 in) length. These sizes assume a transducer is looking down on a perfectly oriented fish from above. This is typically the case when looking down on a fish. When looking from the side, however, fish may not be perfectly oriented parallel to the transducer. When this occurs, a fish target will appear smaller than it actually is due to the reduced cross sectional area of the target. It does not affect the overall population estimate, but likely causes biases where fish are estimated to be smaller than they actually are. Unfortunately, little can be done to rectify this problem. Oftentimes the presence of strong current in the river did help minimize this effect as fish typically orient themselves into the current, and transducers are oriented to look perpendicular to the current.

The direction of travel is calculated as an angle varying between 0 and 360º. The split-beam coordinate system may be considered as a compass, with north oriented in the direction opposite the cable connector on the transducer. This direction would represent 0 degrees. A clockwise rotation of 90 degrees would indicate a direction corresponding to East. Depending on how the transducer was mounted, the direction column indicates the vector direction in a plane normal to the acoustic axis, with zero degrees opposite the connector. Thus a fish with direction of between 0.1 degrees and 179.99 degrees would be considered as going from left to right across the transducer face. For this study any graphics where direction of travel is indicated, 0–179.99 degrees indicate fish are moving upstream in the direction of Rio Vista. Typically observations for a fish are near 90 or near 270 degrees (straight upstream, or straight downstream. An average movement near 180 degrees is indicative of no directional preference.

The SonarData software package, Echoview v4.x® (Myriax Software, Hobart, Tasmania) was used to analyze all data. The echogram was reviewed to locate individual fish targets, which were acquired and logged to data files. An amplitude threshold was used to reject echoes smaller than a predetermined voltage, and areas of high acoustic noise were manually removed from the raw echogram data prior to analysis, by defining a line or region below for which any data is ignored during the analysis phase (Figure 38).

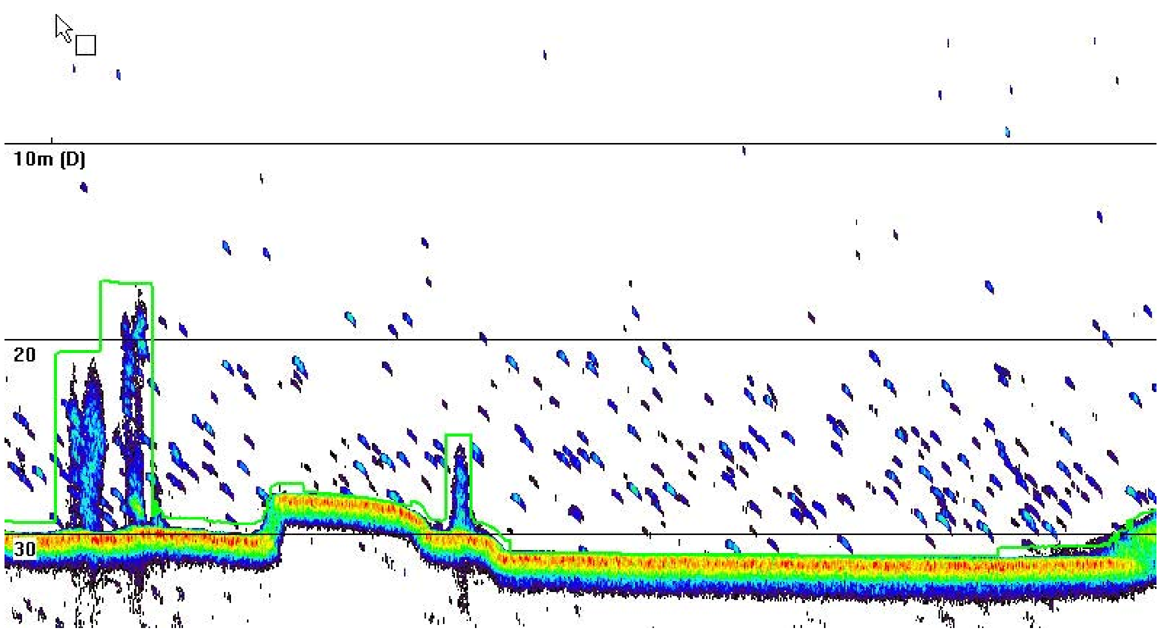


Figure 38- Example of downward looking target data showing fish targets, noise, and bottom. A light green line is shown in going up and around the noise on the lower left and then following the trace of the bottom for the rest of the echogram. During analysis, all data below this line is excluded.

Analyses of acoustic data consisted of a series of post-processing steps, designated as

a) Observation
b) Calibration and Thresholding
c) Regions for Exclusion (Noise)
d) Echo Extraction
e) Trace Formation (Fixed Station)
f) Output Formatting/Quality Assurance

These steps are described in detail in Appendix 11.5.

5.1.2.1 Fixed Station Analyses

Analysis of fixed station data was primarily designed to assess behavior of fishes in and around the location of the release pipe. Units collected data continuously during each sample period. Data was then sub-sampled, into four 24–hr periods during each period for analysis. Raw target data was collected and analyzed as per the preceding section. The collection threshold filtered out all targets smaller than -45 dB or about 9.5 cm (3.7 in). This effectively removed a lot of the smaller debris as well. All the remaining data was analyzed as fish tracks for this portion of the study.

All data was presented graphically using Sigmaplot 10®. For presentation and analysis data were organized into one-hour time bins. Hourly movement was analyzed by examining changes in numbers of fish observed passing each transducer over time. A similar approach was taken to map out the average target strength of fish in the area, direction of movement, and average range from the release pipe. This data was examined seasonally, tidally, in relation to day-night, and in response to releases of fish.

5.2.2.2 Mobile Survey Analyses

Mobile survey data was used to compare fish densities of predator sized targets between the release and two control sites, as well as to estimate total population biomass of smaller fishes in the area to help estimate the contribution of fish from the release site. Population estimates of large fish were used to estimate potential predation in the area.

Analysis of individual targets was used to determine abundance of fishes. Fish targets were output in 100 ping bins. A density (fish/m^3) was calculated by taking the number of targets and dividing it by the sum of the volume sampled by the acoustic beam each period. For one sampling event (set of transects) the number of targets of a given size class was summed up and divided into the total volume of water sampled. To determine a population estimate for each site, this number (fish/m^3) was then multiplied by the number of cubic meters of water in a given area. The volume of each area was determined by determining the surface area of the reach (Figure 39) and multiplying it by the average depth of the set of transects for that site. This was adjusted each sampling period to account for depth differences due to tidal stages. This technique assumes a uniform fish distribution and may result in population estimates biased high, but comparisons between sites are still relevant.

Fish were binned out to two size classes, those > -36 dB (25 cm [9.8 in]), and all fish larger than -45dB (9.5 cm [3.7 in]), for down looking data and -36 dB (25 cm [9.8 in]) and -40 dB (18 cm [7.1 in]) for side looking data. A more restrictive threshold was used for the side looking data due to the amount of noise in the water column due to air bubbles from the almost constant winds in the area.

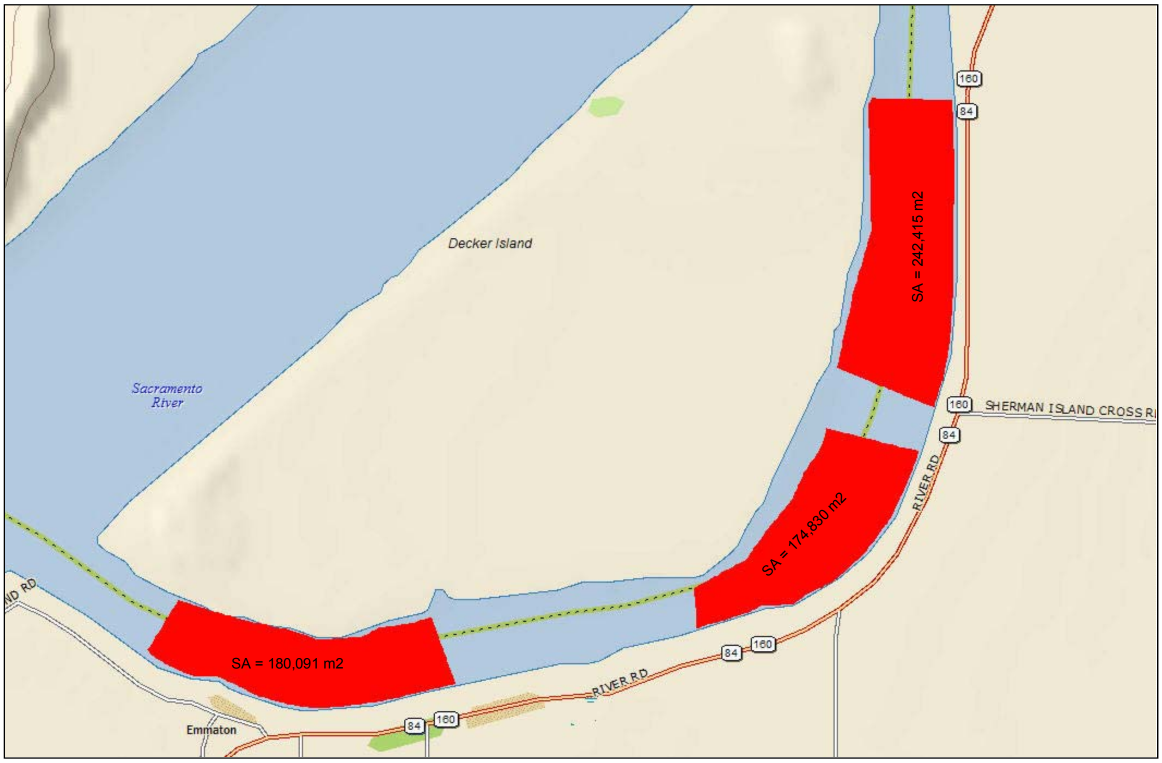


Figure 39- Surface area (SA) and approximate region of coverage used in fish population estimates for the release and two control sites. Note the left side of the middle site does not come near shore. The map is based on the shoreline. This section of the river averages only about 0.3 m (1 ft) in depth and is weed choked. It was felt this area did not contribute to the available habitat.

5.1.3 Bioenergetics

The bioenergetics approach employed in this study is based on an energy balance equation. For this portion of the study the *Fish Bioenergetics 3.0* (Hanson and others 1997), commonly called the Wisconsin fish model, was employed. The model has been used for a wide variety of applications and has been parameterized for a number of common species, making for a relative ease of use. Consumption shown as grams of prey consumed per gram of predator per day is the output of the model used for this study. This estimate is based on species and age specific metabolic processes, energy density of the prey, proportion of prey in the diet, and growth rate of the predator.

Model results were developed for common predatory species in the study area, including striped bass, largemouth bass, and Sacramento pikeminnow. Initially electrofishing data was to be used to determine the types of predatory species present, but electrofishing data was heavily biased to fish closely associated with the shoreline. Observations from the DIDSON camera, and other referenced studies (Pickard and others 1982) were used to determine the likely makeup up the predator community. The model results were outputted for a variety of potential configurations of which species dominated the community.

Bioenergetics parameters for the striped bass were those provided with the model and were developed by Hartman and Brandt (1995). Largemouth bass data were derived from Rice and others (1983). Data specifically for the Sacramento pikeminnow was not available, and for the purpose of this study the coefficients obtained from studies on Northern pikeminnow (*Ptychocheilus oregonensis*) in the Columbia River basin (Peterson and Ward 1999) were used. Swimming speed can have a significant impact on consumptions estimates in the model, and therefore was held as a constant.

Size ranges of predators potentially impacting the release site were based on the results of both the fixed and mobile acoustic surveys. Water temperature data was collected daily using a temperature logger at the site. Employing temperature data also allows for the calculation of seasonal variation in daily consumption rates as a function of water temperature. Based on fish count data from the SDFPF, an assumption was made that the majority of fish present in releases were predominately threadfin and American shad since they typically dominate the fish salvage for most of the year. For these species an average energy density of 5,600 joules/gram wet weight was used and assumed not to vary over the course of the study. Average growth rates for predatory species were obtained from studies reported in the literature though specific growth data was not available for this area (Kimmerer and others 2005, Brown 1990, Hasler 1988, Vondracek and Moyle 1982, Scofield 1931, Tucker and others 1998).

The approach taken here is rather simplistic in that several assumptions are made: (1) that predators are eating only fish, (2) that the different species are opportunists and do not differentiate between prey species instead consuming them in proportions relative to what is being released, and (3) that the predator assemblage is known. If growth rates are different, or the predator species assemblage proportions used are different from what truly exists, the model will have bias. However, as a broad generalization the model will provide an initial estimate of predation mortality.

5.2 Results and Discussion

5.2.1 Releases

Review of SDFPF salvage data shows increases in the numbers of fish released beginning in June and July, with a peak in August. The number of fish being released decreased significantly by October, and then continued at low levels through the winter, with the exception of a pulse observed in mid-December (Figure 30, Table 19). Salvage data indicate that, over a typical year, the bulk of fish biomass is composed of threadfin and American shad. Other species typically comprise only a small proportion of the total. Based on the assumption shad compose the majority of the release, the total biomass for each release was estimated using an average sized shad as a starting point. Therefore, assuming that an average shad is about 90–110 mm (3.54–4.53 in) in length and weighs about 13g (0.028 lb), for every 1,000 fish released, about 13 kg (28.6 lb) of biomass is released into the river at the SWP Horseshoe Bend release site.

Correlating releases to predator behavior was a central tenet of this study, however, when compiling release dates, times and locations from the SDFPF data sheets, numerous inconsistencies in the data became apparent. Time of release was not difficult to estimate as it reliably was one to one and a half hours following the time the truck left the SDFPF, which was recorded on data sheets. This assumption is based on typical travel time and observations of release truck operations at Horseshoe Bend. However, records for location of release did not agree with observations of releases conducted during DIDSON monitoring. As a result, there was no way to determine where a release occurred on days during which no DIDSON monitoring was conducted. To test hypotheses associated with predator response to releases of fish, a comparison of behavior for release and non-release periods was planned, but without complete records of where fish were released, the analysis could not be conducted.

Table 19- Numbers of fish released, and time of release during study periods.

Date	# of Fish Released	Location *	Time
8/10/2007	53756	Horseshoe Bend	1000
8/11/2007	19377	Horseshoe Bend	1000
8/12/2007	10428	Curtis Landing	1200
8/13/2007	16863	Horseshoe Bend	1200
8/14/2007	25808	Curtis Landing	1200
8/15/2007	18535	Horseshoe Bend	1100
8/16/2007	34917	Curtis Landing	1100
10/13/2007	972	Horseshoe Bend	1100
10/14/2007	2790	Horseshoe Bend	1200
10/15/2007	825	Horseshoe Bend	0900
10/16/2007	639	Horseshoe Bend	1100
10/17/2007	651	Curtis Landing	1100
10/18/2007	1338	Horseshoe Bend	1000
12/4/2007	341	Curtis Landing	1030
12/5/2007	319	Horseshoe Bend	1100
12/6/2007	486	Horseshoe Bend	1000
12/7/2007	7299	Curtis Landing	1230
12/8/2007	3973	Horseshoe Bend	1200
12/9/2007	2526	Curtis Landing	1100
12/10/2007	560	Horseshoe Bend	0430
12/11/2007	826	Curtis Landing	1030
12/12/2007	388	Horseshoe Bend	1030
2/2/2008	1324	Curtis Landing	1100
2/2/2008	128	Horseshoe Bend	2000
2/3/2008	2156	Curtis Landing	0800
2/3/2008	276	Horseshoe Bend	2000
2/4/2008	1560	Curtis Landing	0800
2/4/2008	118	Horseshoe Bend	1400
2/5/2008	2168	Curtis Landing	0800
2/5/2008	436	Horseshoe Bend	1630
2/6/2008	272	Horseshoe Bend	1500
2/7/2008	1404	Curtis Landing	0700
2/7/2008	124	Horseshoe Bend	1800
2/8/2008	1184	Curtis Landing	0700
2/8/2008	108	Horseshoe Bend	1500
3/12/2008	188	Horseshoe Bend	0800
3/12/2008	16	Curtis Landing	1200
3/13/2008	84	Horseshoe Bend	0800
3/14/2008	216	Curtis Landing	0800
3/15/2008	42	Horseshoe Bend	0815
3/16/2008	48	Curtis Landing	0800
3/17/2008	122	Horseshoe Bend	0900
3/18/2008	64	Curtis Landing	0800
3/19/2008	172	Horseshoe Bend	0800
3/19/2008	8	Curtis Landing	1300

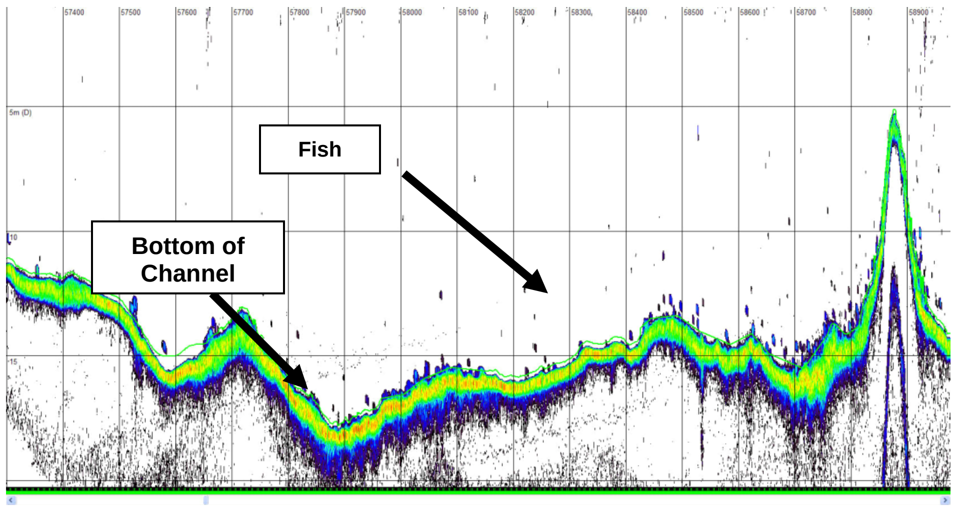
* Location may not represent actual release site

5.2.2 Acoustic Data

When examining the data, numbers of fish observed by each transducer do not necessarily agree in number as Figure 41 illustrates. The orientation of each transducer can cause this type of disagreement in estimated numbers of fish. As an example, using Figure 41, CH1 HPR is the most Westerly facing transducer. This transducer points almost directly downstream, away from the release site. CH2 HPR is oriented slightly more north (approx. 30°), CH1 NHPR more so, and finally CH2 NHPR is the transducer aimed almost across the front of the release pipe, and therefore would be expected to see fish most directly suspended near the release pipe.

Differences in mobile data stem from how each transducer samples the water column. In an ideal setting (eg. fish are randomly distributed in the water column and there are a sufficient number of targets detected to produce meaningful density calculations) both down looking and side looking data should produce the same estimated fish density. However, an ideal setting is rarely the case. Fish population estimates obtained at night also tend to differ from those obtained during the day. This is a common phenomenon, and the primary reason most acoustic surveys are done at night. Typically many species of fish will seek cover during the day or associate closely with bottom structure (Figure 40). When they do this, visualizing fish targets is difficult. The 0.4 ms pulse width used in this study prevents identification of individual targets closer than 28 cm (1 ft) from structure such as the bottom, or from each other. Aside from the differences mentioned above, trends are typically the same or similar for each transducer for either the fixed station or mobile survey data.

Day time distribution, most fish are near the substrate.



Night time distribution, fish have moved up into the water column.

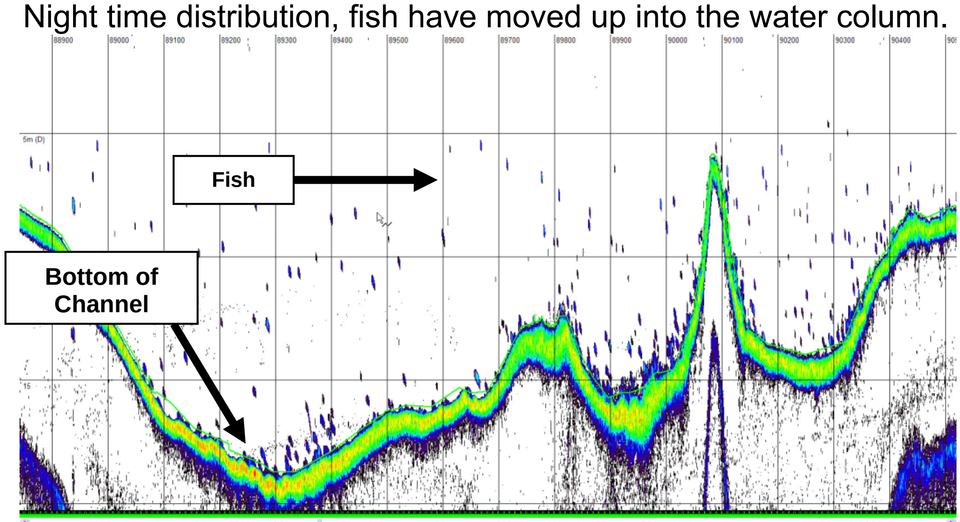


Figure 40- Echogram snapshot showing differences in day and night distribution of fishes.

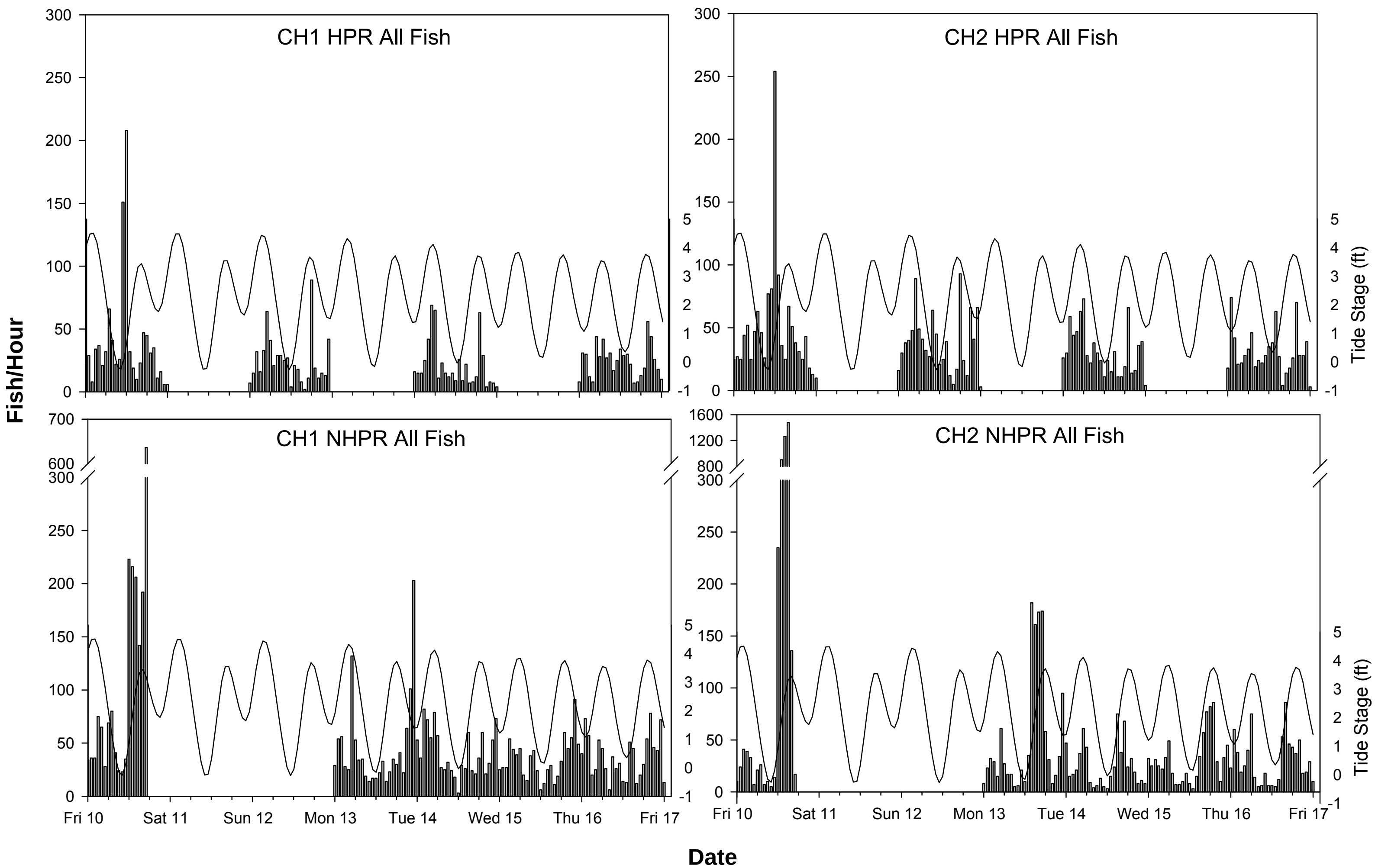


Figure 41- August 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45dB or 9.5cm (3.7 in)

On average, activity of large fish (>-36 dB or 25–26 cm [9.8–10.2 in]) in the local vicinity of the release site peaks in August and October then declines through the rest of the study period (Figure 42). By March the numbers have declined to very low levels and on average only 4-5 large fish per hour or fewer, depending on the transducer, are observed. The pattern for smaller fish shows more consistent numbers through December then a decrease in February and March (Figure 43). This pattern differs from the population trends observed during the mobile surveys, where pelagic densities of fish tended to peak in December and be lower both prior to, and after that time period (Figures 44–47). The December peak also coincides with an increase in numbers of fish being captured at the SDFPF during the second week of December (Table 19).

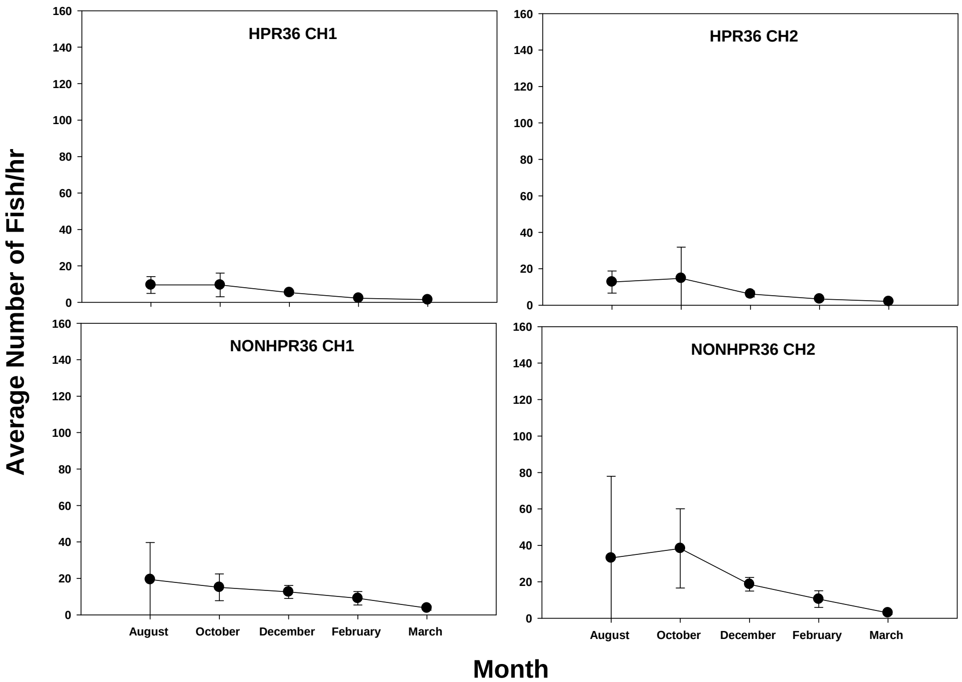


Figure 42- Average number of fish per hour larger than -36 dB (25–26 cm [9.8–10.2 in]) encountered at the release site based on **fixed transducer** data. Bars are plus or minus 1 standard deviation.

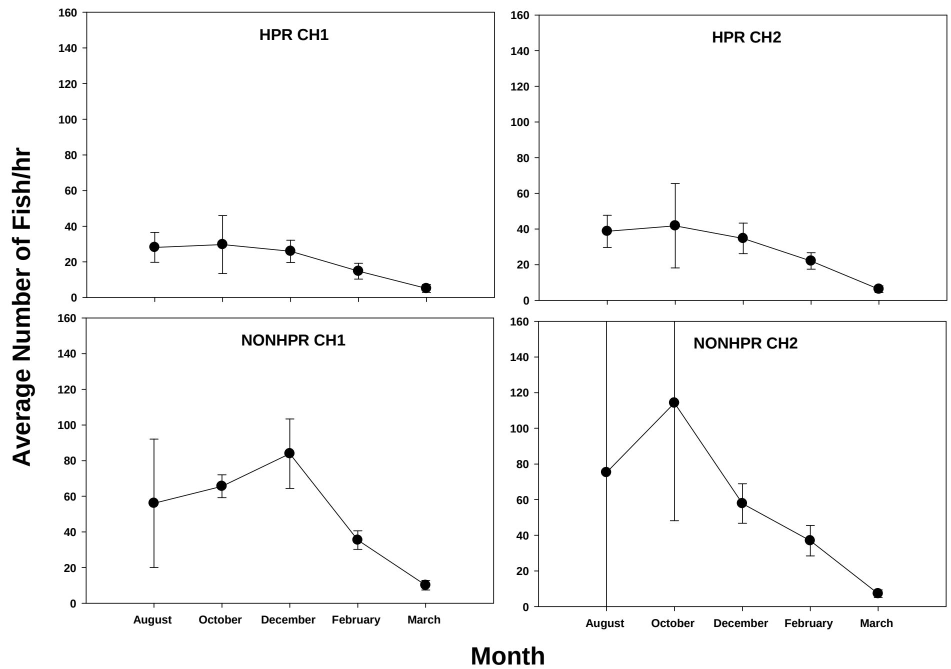


Figure 43- Average number of fish per hour larger than -45 dB (9.5 cm [3.7 in]) encountered at the release site based on **fixed transducer** data. Bars are plus or minus 1 standard deviation.

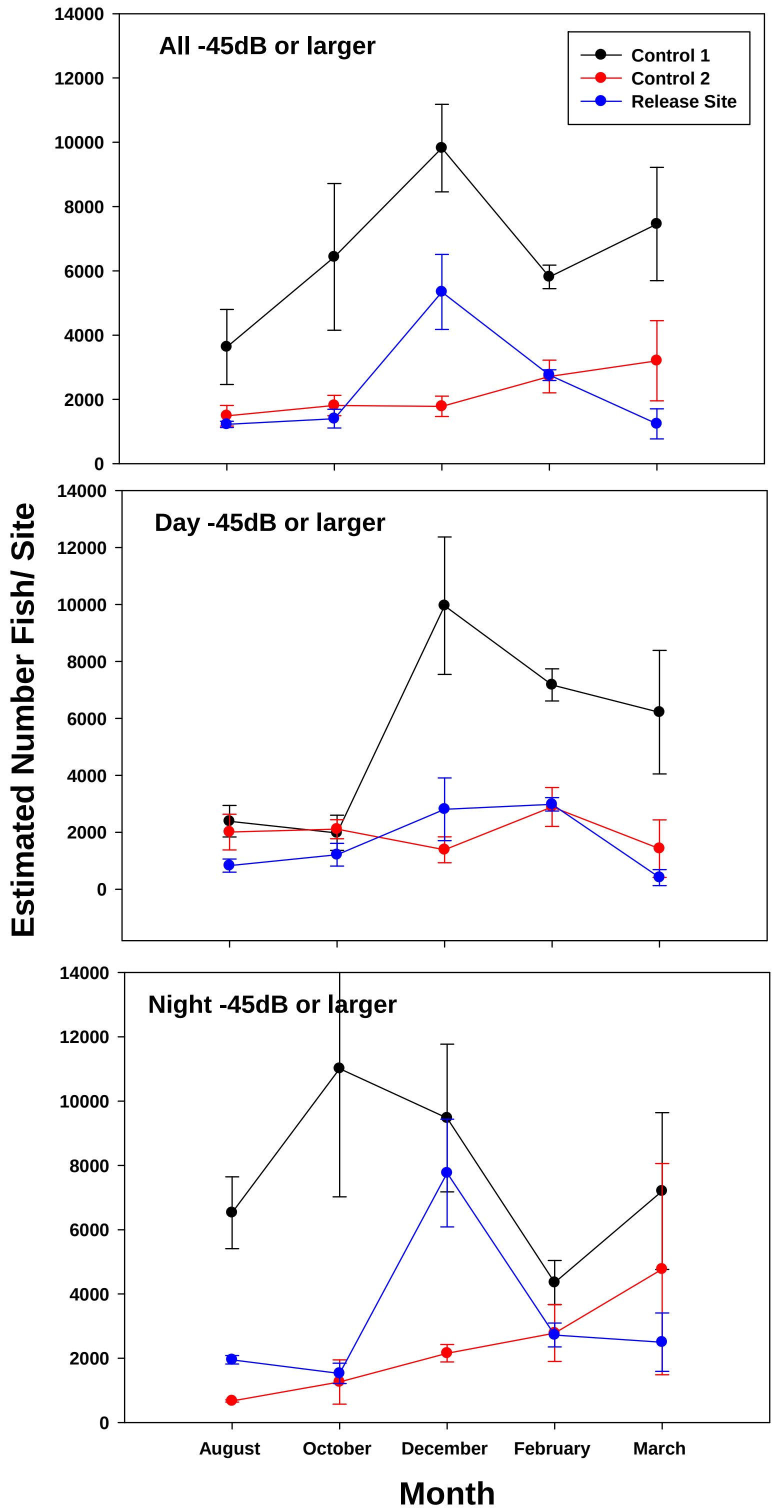


Figure 44- Estimated fish populations (day and night, day only, and night only) for fish larger than -45 dB (9.5 cm [3.7 in]) for the three sites at Horseshoe Bend based on Mobile acoustic surveys using a **down looking transducer**. Error bars are ± 1 SE.

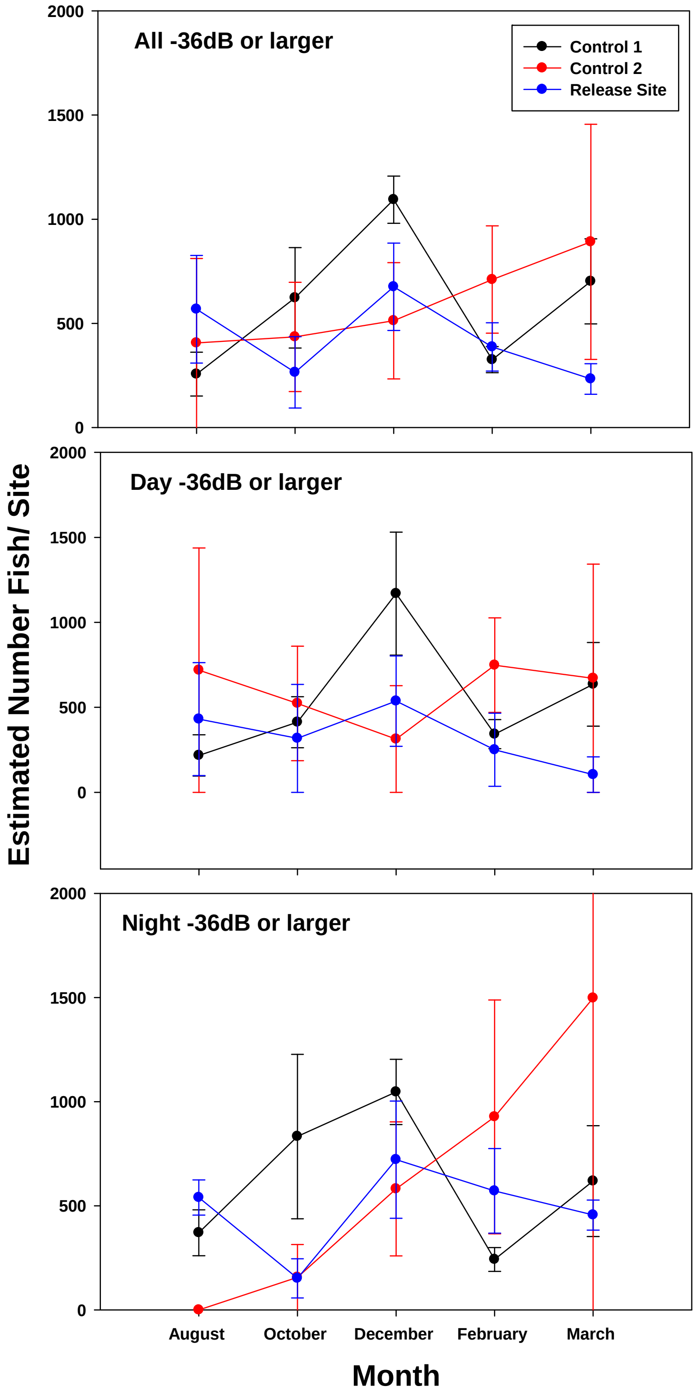


Figure 45- Estimated fish populations (day and night, day only, and night only) for fish larger than -36 dB (~25 cm [9.8 in]) for the three sites at Horseshoe Bend based on Mobile acoustic surveys using a **down looking transducer**. Error bars are ± 1 SE.

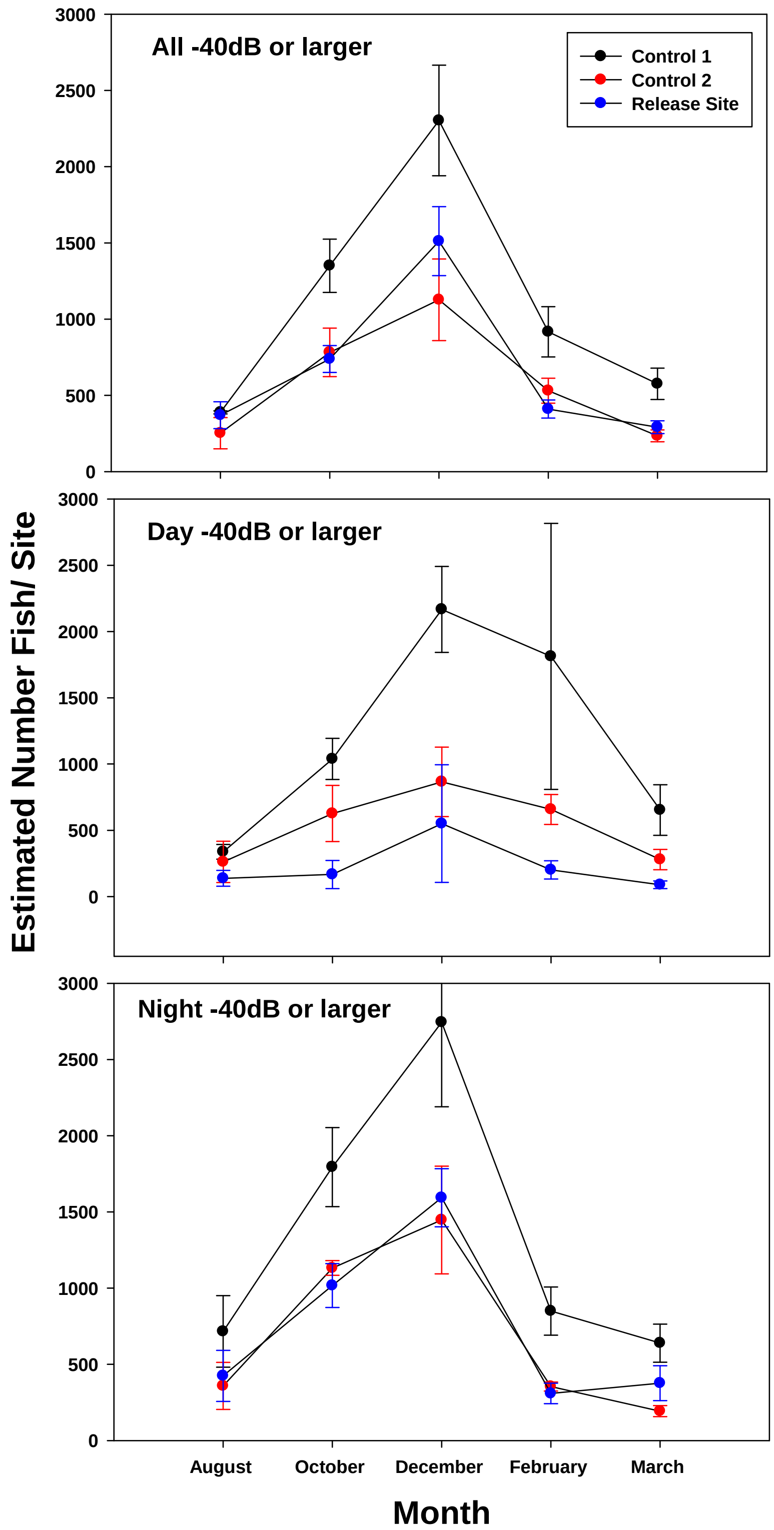


Figure 46- Estimated fish populations (day and night, day only, and night only) for fish larger than -40 dB (~18 cm [7 in]) for the three sites at Horseshoe Bend based on Mobile acoustic surveys using a **side looking transducer**. Error bars are ± 1 SE.

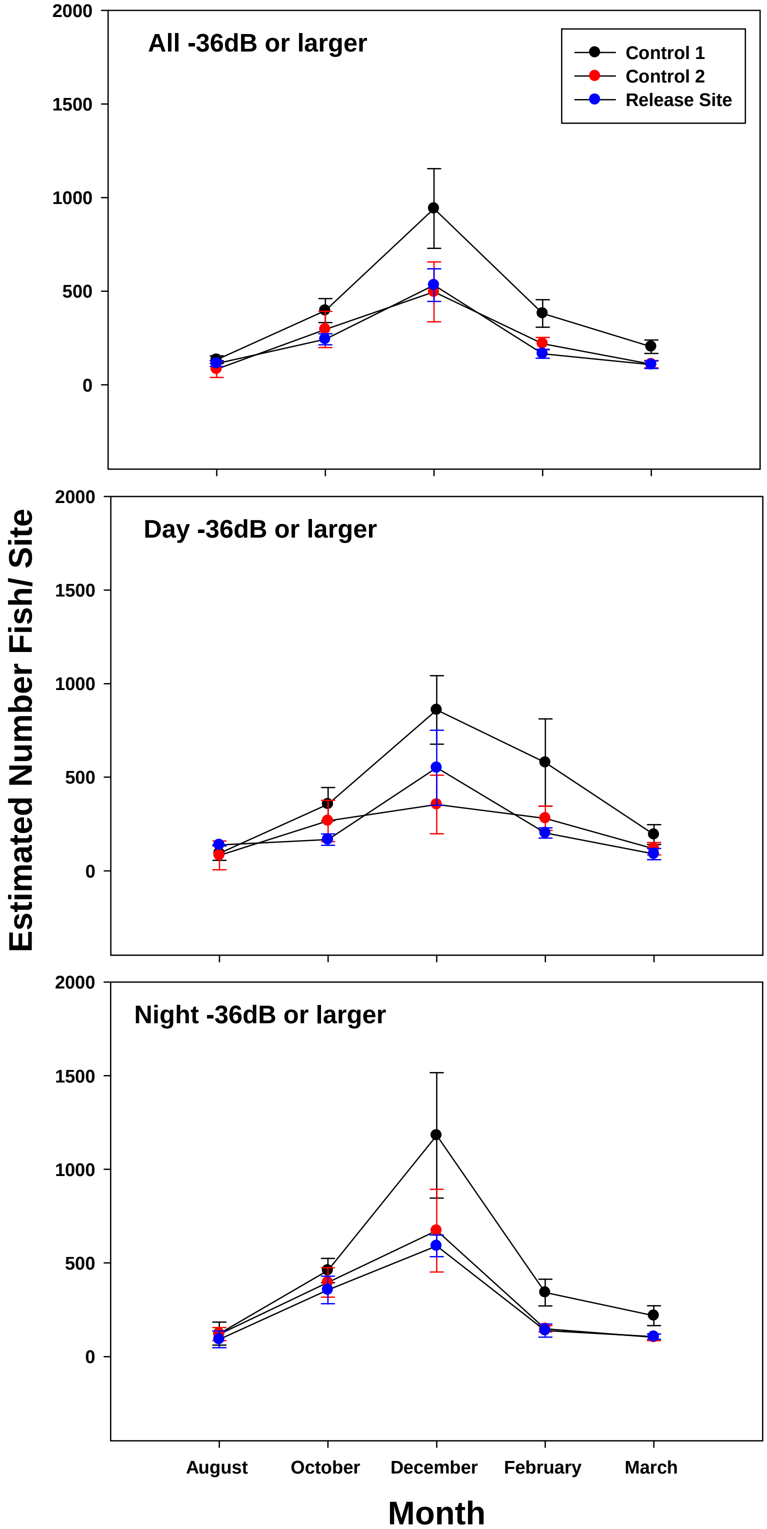


Figure 47- Estimated fish populations (day and night, day only, and night only) for fish larger than -36 dB (~25 cm [9.8 in]) for the three sites at Horseshoe Bend based on Mobile acoustic surveys using a **side looking transducer**. Error bars are ±1 SE.

Using sidescan acoustic data, densities at the release and control sites were higher during December 2007 than at any other times when comparing populations of both small and large fish (Figures 43–47). Although the data was much noisier, downlooking acoustic samples revealed the same general trend. The less defined pattern associated with the downlooking data is a function of the volume of water sampled. For a 100 ping block the average summed volume of water sampled is approximately 55 m^3 (1,942 ft^3), the same 100 ping block using sidescan data samples about 3,000 m^3 (105,944 ft^3). The relatively small volume of water sampled using the down looking transducer means a small change in number of targets has a large impact on calculated densities of fish. With sidescan, the volume sampled is more than an order of magnitude larger, consequently small variation in the number of targets observed has little impact on the overall population estimate. The size of the error bars for the population estimates are indicative of the effect the different sampling volumes have (Figures 44–47). These differences aside, the average population estimates for large fish are fairly similar, and likely indicate that the population was effectively sampled.

Population estimates for all fish larger than -45 dB, provide a useful starting point to examine the potential impact salvaged fish releases have on the Horseshoe Bend area and why predators might congregate at the release pipe versus feeding in the open channel. In August the populations of fish larger than -45 dB, or 9.5 cm (3.7 in), observed using the downlooking transducer, which for this study provides the most conservative estimate of predatory fish populations, varied between about 1500 fish for the release and Control Site 2, and about 4,000 for Control Site 1 (Figure 44). During this time of year, on a given day, anywhere between 10,000 and 50,000 salvaged fish may have been released into the area; an order of magnitude larger than the local pelagic population (Figure 48). This influx of fish was substantial in relation to the standing predatory fish population in the area. During the other sampling periods the number of fish released tended to approximate the fish populations in each reach, with numbers ranging to slightly above the population estimates to well below. By March, the numbers of fish released were a fraction of the total estimated fish population of any of the sites monitored.

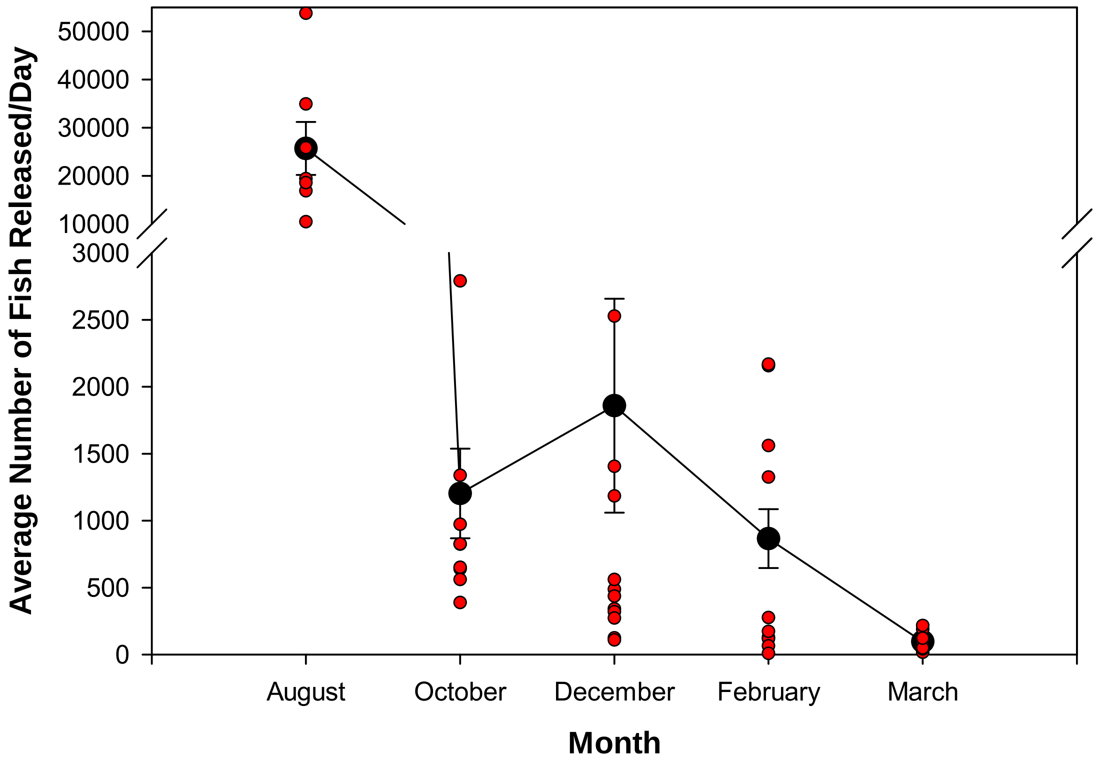


Figure 48- Average number of fish released/day during each study period. Data shows both SWP Horseshoe Bend and Curtis Landing releases since it is not known where the release occurred. Black circles are mean for the time period, red circles represent actual values, and error bars are ± 1 SE.

The observation that fixed site data tend to show an ever decreasing trend for large predator sized fish over time, and do not mimic patterns observed for the mobile surveys is likely indicative of a lessoning response of predators to releases being made. This corresponds to DIDSON observations showing fewer and fewer fish located near the exit of the release pipe as the season progresses. The reason for this decrease is uncertain, as there may be multiple causes. First, the number of fish released each day drops significantly in the winter, when only a couple of hundred small fish are released each day as stated previously. The decrease in numbers of fish being released may result in an unreliable food source such that predators at this time of year no longer associate the site with food. Secondly, at least in December, small fish populations are higher in the open water and may represent a better feeding opportunity than the fish releases. Third and most likely, as water temperatures decrease in the winter, predator species feeding rates, as a function of temperature, drop to only a fraction of summertime rates and there is no real payoff to hold in front of the release site.

Mobile acoustic surveys also reveal that if predators are responding to the release site, it is likely a local grouping. Population estimates of large fish indicate both spatial and seasonal differences in density of large fish among the three sites (Figures 46 & 47; $F_{2,69} = 4.34$, n=70, p=0.01 (location), $F_{4,69} = 14.31$, n=70, p<0.01 (month), $F_{8,69} = 0.79$, n=70, p=0.6 (interaction)). Least squares analysis, however, indicates Control Site 2 and the release site were not different from each other, while Control Site 1 was different from both the other sites. A similar trend was observed when looking at all fish ($F_{2,69} = 9.42$, n=70, p<0.01 (location), $F_{4,69} = 24.64$, n=70, p<0.01 (month), $F_{8,69} = 1.25$, n=70, p=0.28 (interaction), with least squares indicting the release site and Control Site 2 were similar to each other while Control Site 1 held higher fish populations. When these sites were initially selected they were chosen based on their apparent similarities, in that all three have some sort of water structure extending out on pilings, and have fairly similar shoreline topographies. Control Site 1, however, also was found to have a deep hole near the mid-point of the site, making this site somewhat dissimilar from the other two in this respect, and fish tended to congregate in this area. Figure 49 shows the large concentration of targets in the bend of the river where the deep hole is, whereas there is no obvious larger scale association with the area around the release pipe.

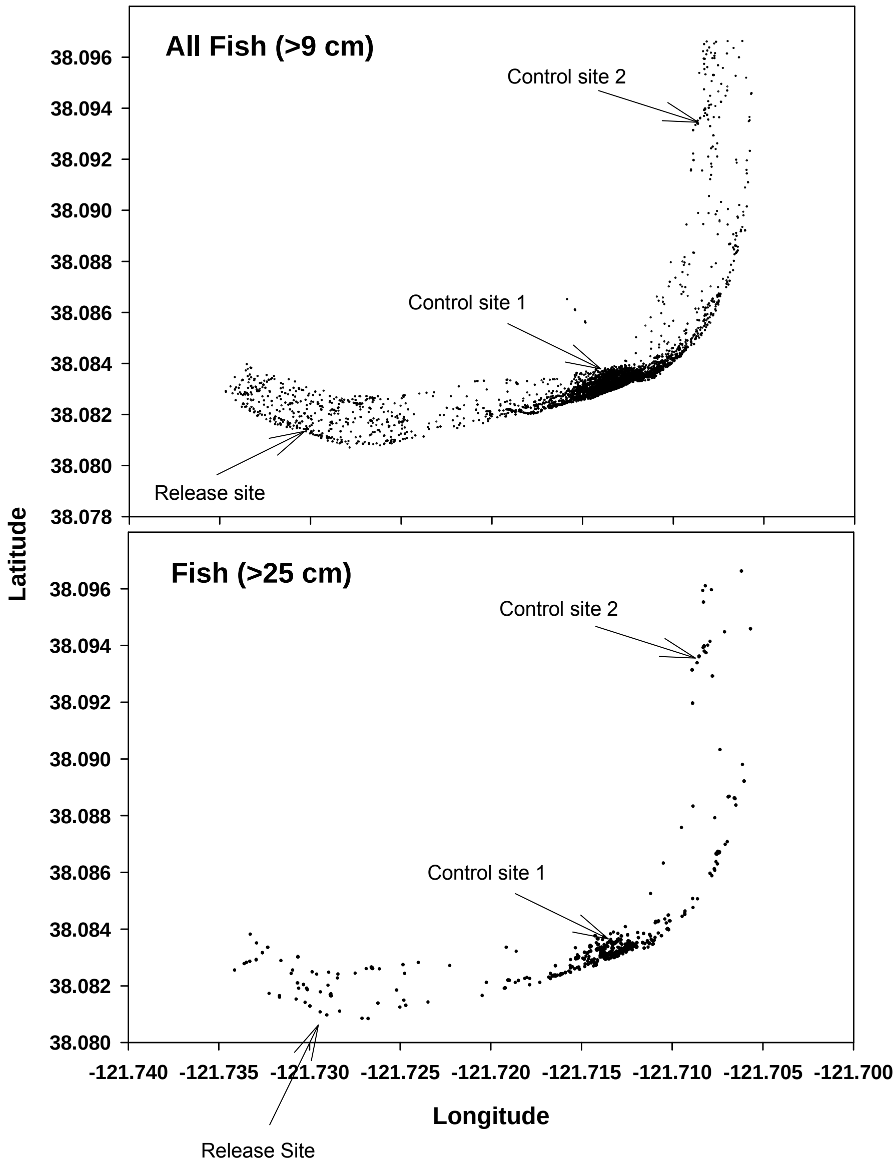


Figure 49- Distribution of fish targets in the Horseshoe Bend Area.

Generalized patterns of movement of fish in the area surrounding the release site show some slightly different patterns when comparing the four transducers. Again transducer CH2 NHPR looked most directly at the release pipe, and predominately saw fish in this vicinity, while the other transducers were not quite as heavily influenced. When lots of fish were present near the release pipe, mainly in August and October, the net direction of movement of fish was often near 180 degrees, indicating as many fish were going down stream as upstream. This can be interpreted as milling behavior in front of the release site, and is supported by the relatively high number of targets observed there. The other three transducers were less impacted by fish immediately in front of the release site, instead looking more at the general fish population in the river. Using Figure 50 as an example, CH2 NHPR and CH1 NHPR show no real pattern of directionality in response to tidal phase, as fish holding near the transducer dominated the signal, while the other transducers do show some tidal response. The tidal response shown is highly variable; however, the trend is for smaller fish to follow the direction of current in the reach (Figures 51 & 52). Large fish are somewhat less likely to follow the tidal flow than small fish, as indicated by the lower r-square values for the plots. Although this relationship is significant, the variability is high and probably extends from the fact the river current in this reach is not particularly strong.

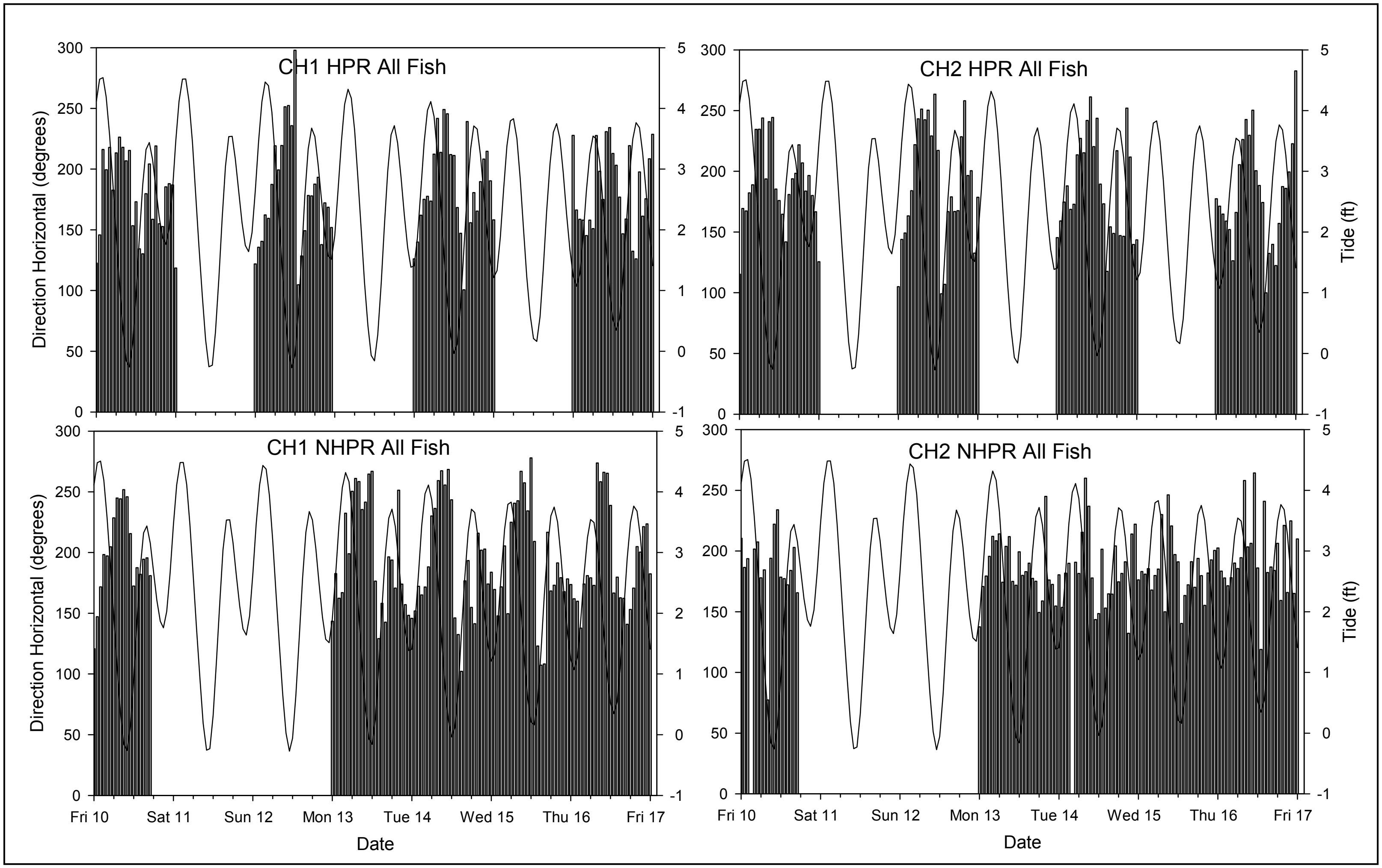


Figure 50- August 2007 fixed site releases, average direction of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

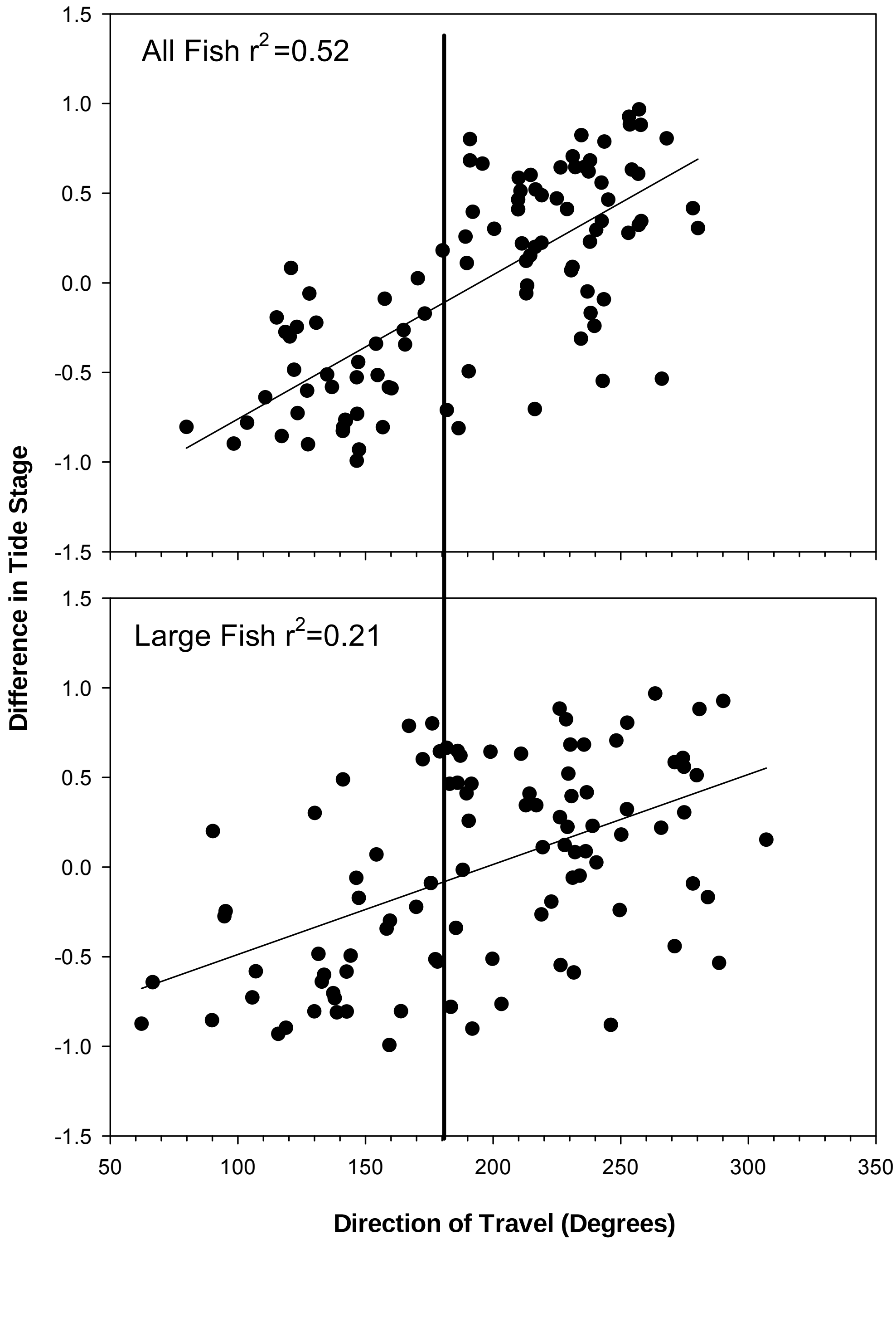


Figure 51- Average direction of movement based on tidal phase. Positive numbers indicate an outgoing tide, negative an incoming tide. Differences are based on hourly stage changes for a study period. In this case data is shown for NHPR CH1, February 2008.

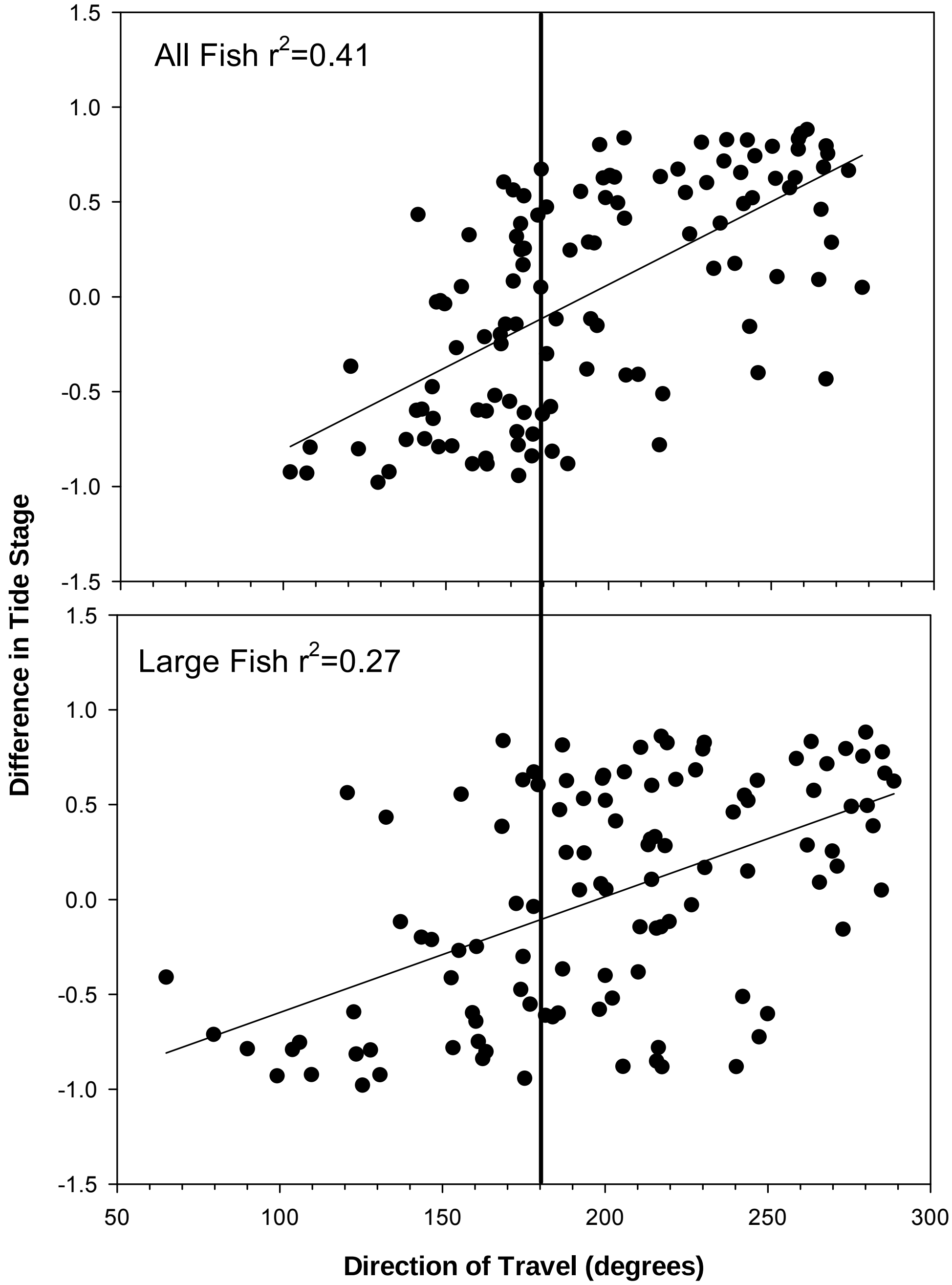


Figure 52- Average direction of movement based on tidal phase. Positive numbers indicate an outgoing tide, negative an incoming tide. Differences are based on hourly stage changes for a study period. In this case data is shown for NHPR CH1, August 2007.

On a diel basis it was difficult to determine if there were any consistent trends in fish behavior that were driven by the light-day cycle. At the release site the largest pulses of fish were typically observed during daylight hours (Figures 53–62). This, however, may simply be a learned response from fish that associate the release site with food. However, in December there tended to be more nocturnal activity (Figure 55). Population estimates in December also showed an overall increase and these two together may indicate something else was occurring during December. There was a shift in the time of releases and this may explain the difference in fish activity and population estimates during this time period. Typical release times at SWP Horseshoe Bend tended to occur twice a day and typically near dawn and dusk during December. This is in contrast to the late morning to mid-day releases that had occurred prior to this time. If predators were responding to releases, this change in observed activity may have been a response to changes in the release schedule.

When trying to describe changes in predator behavior in response to releases, a more descriptive approach was employed instead of applying a rigid statistical analysis. As mentioned previously this largely stems from the fact the correct location of fish releases cannot be reliably determined from the SDFPF data sheets. This aside, there does seem to be a significant increase in the number of fish per hour observed at the release site coinciding with the release of fish at certain times of the year (Figures 53–62). The transducer aimed most directly at the pipe showed the greatest increase in activity at these times. The increase in numbers observed, though, is not necessarily a linear response to the number of fish present in the vicinity of the release pipe. However, this may simply represent an increase in activity of fish already in the area. The same fish can be counted many times when moving back and forth in front of the transducer.

Following release, the length of time an increase in fish movement/activity was observed was highly variable. An increase in fish movement activity was observed to last for 6+ hours following a release on August 10 (Figure 58). Similar observations can be made for releases on August 13 and 15. The length of time activity increases following a release may be a general increased activity, or could be a result of fish being trapped in the pipe following release and slowly exiting the pipe. Observations in 2007 using a remote camera indicated that following a release, numerous fish and pieces of debris remain in the pipe. Over time these “trapped” fish may slowly exit the pipe, resulting in a protracted stream of prey fish being available to predators in the area.

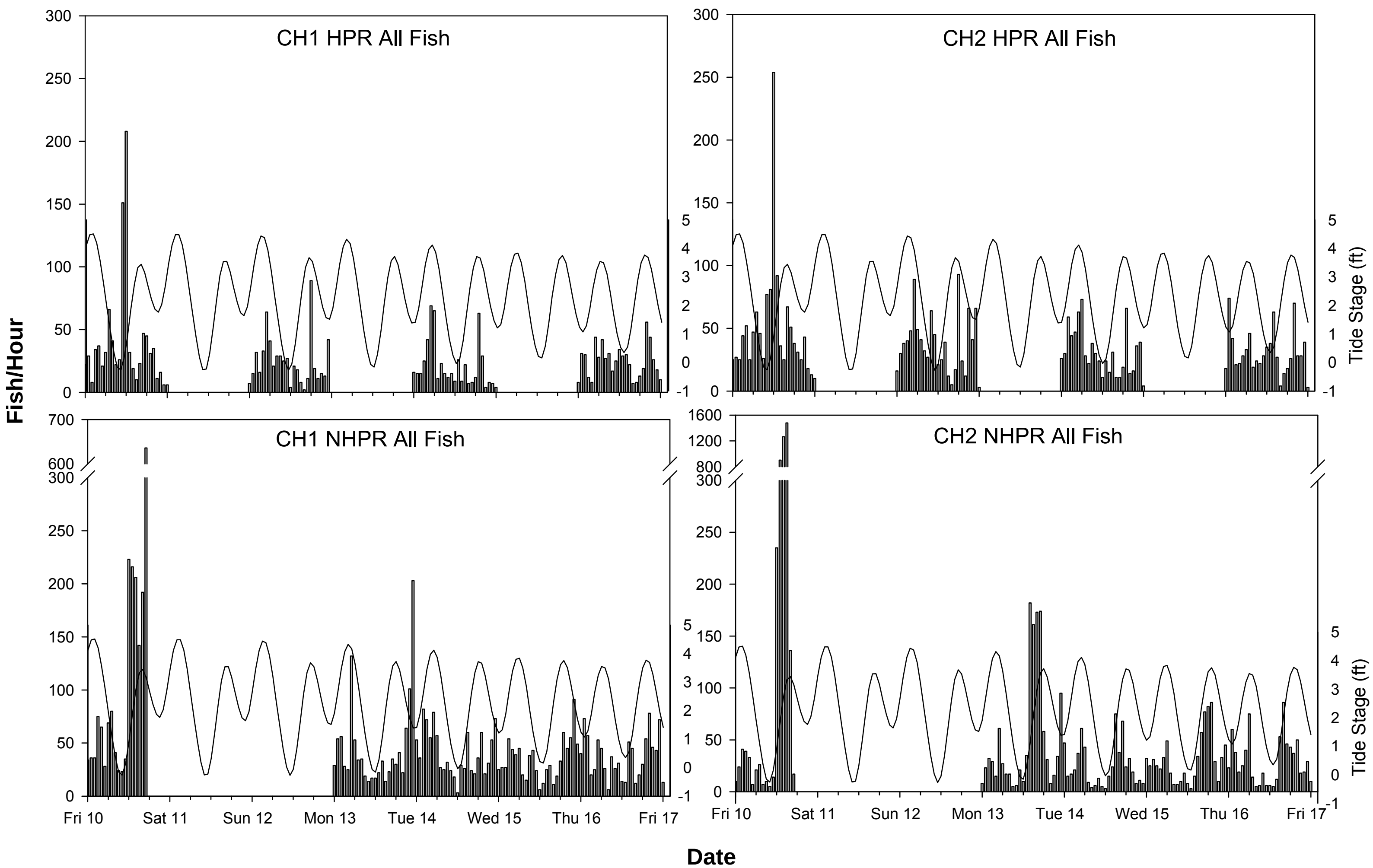


Figure 53- August 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

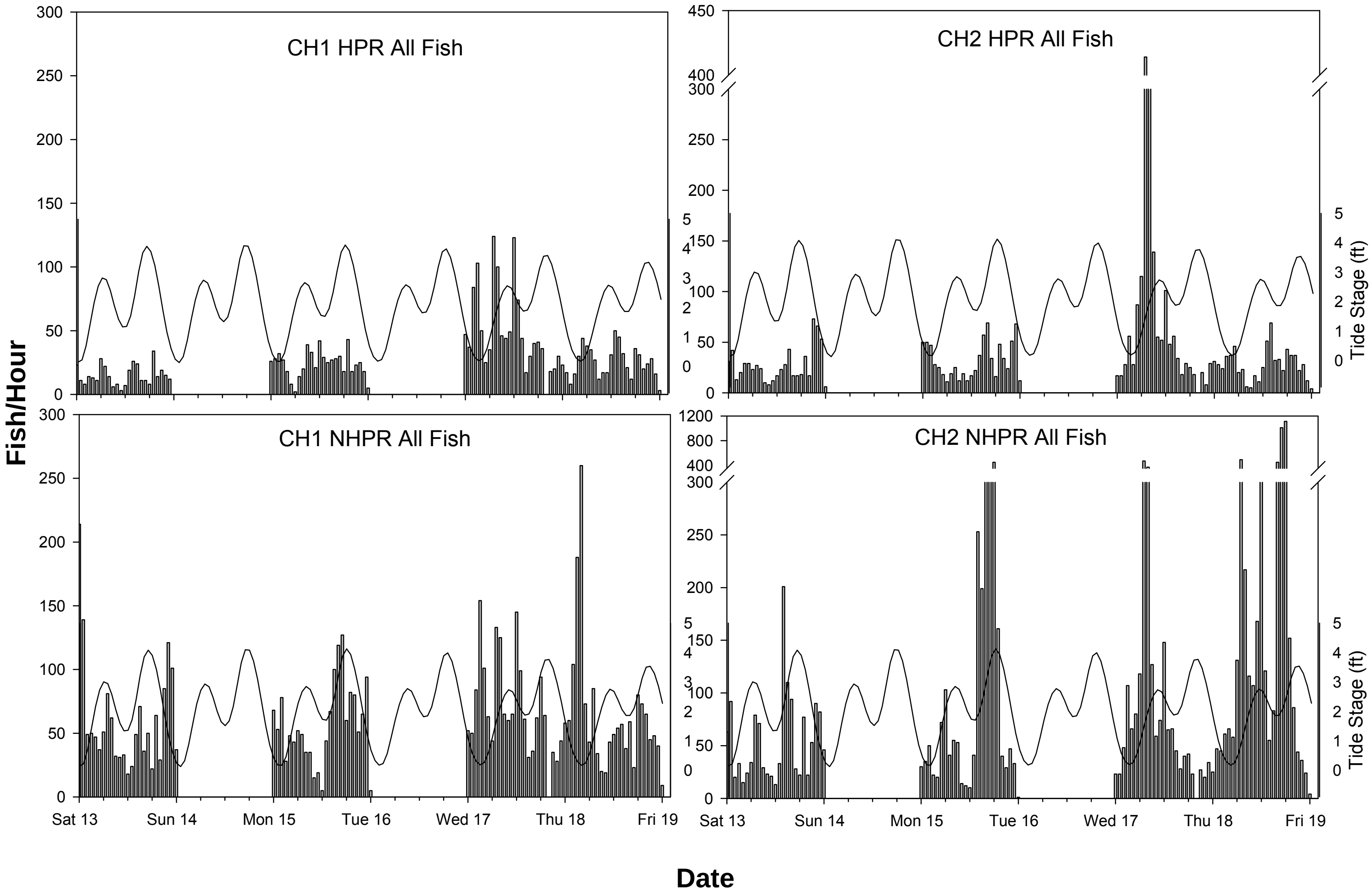


Figure 54- October 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

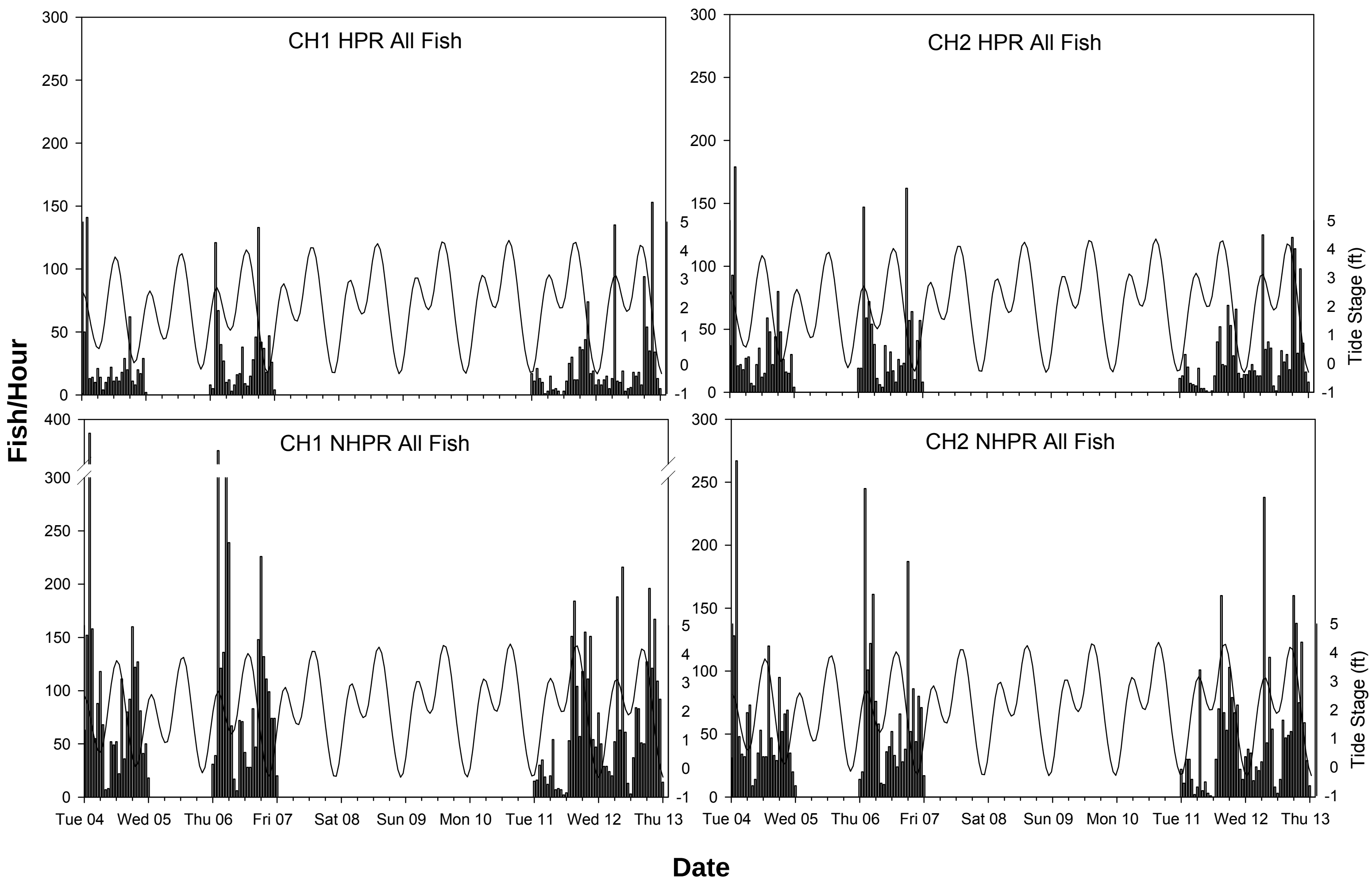


Figure 55- December 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

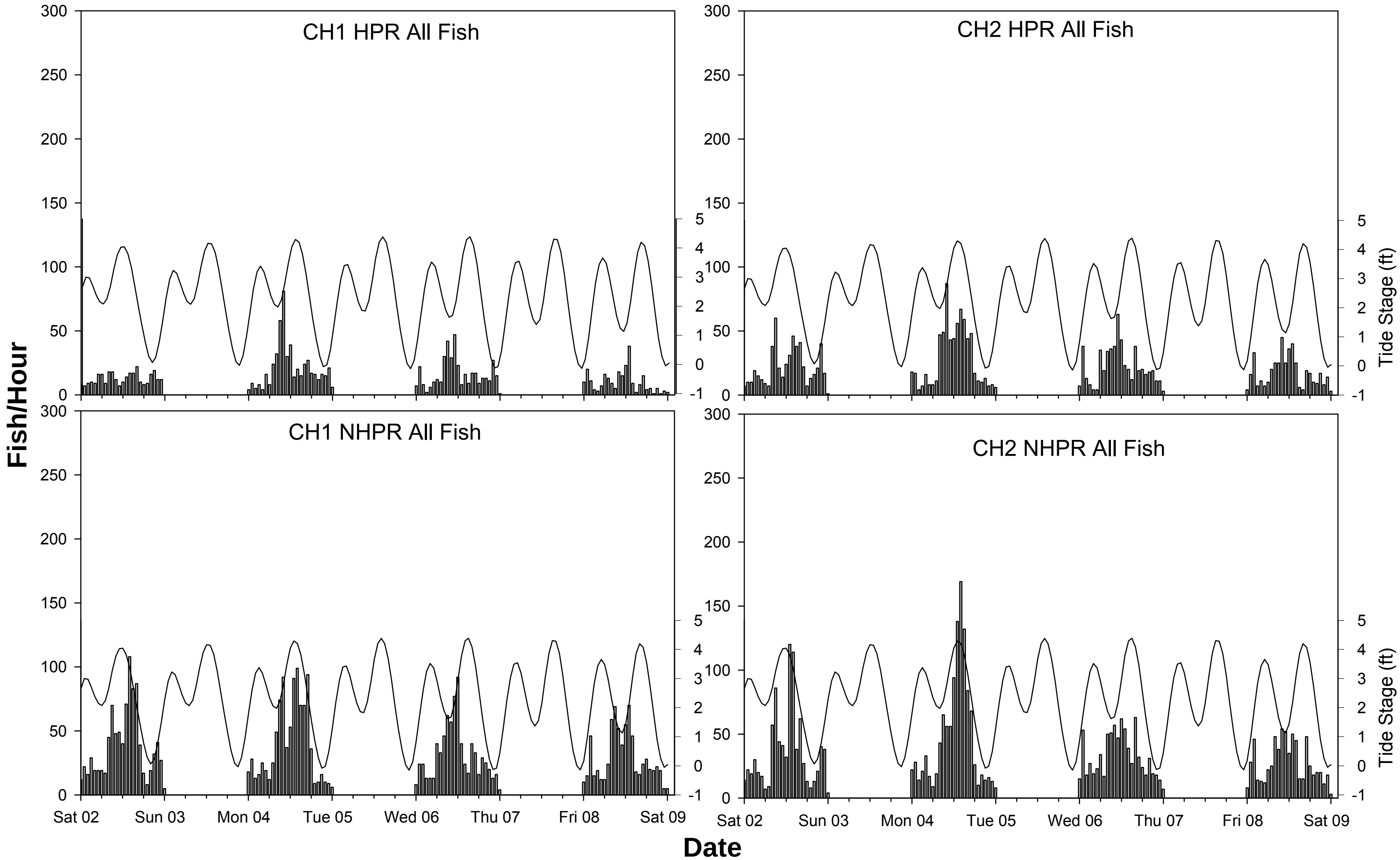


Figure 56- February 2008 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

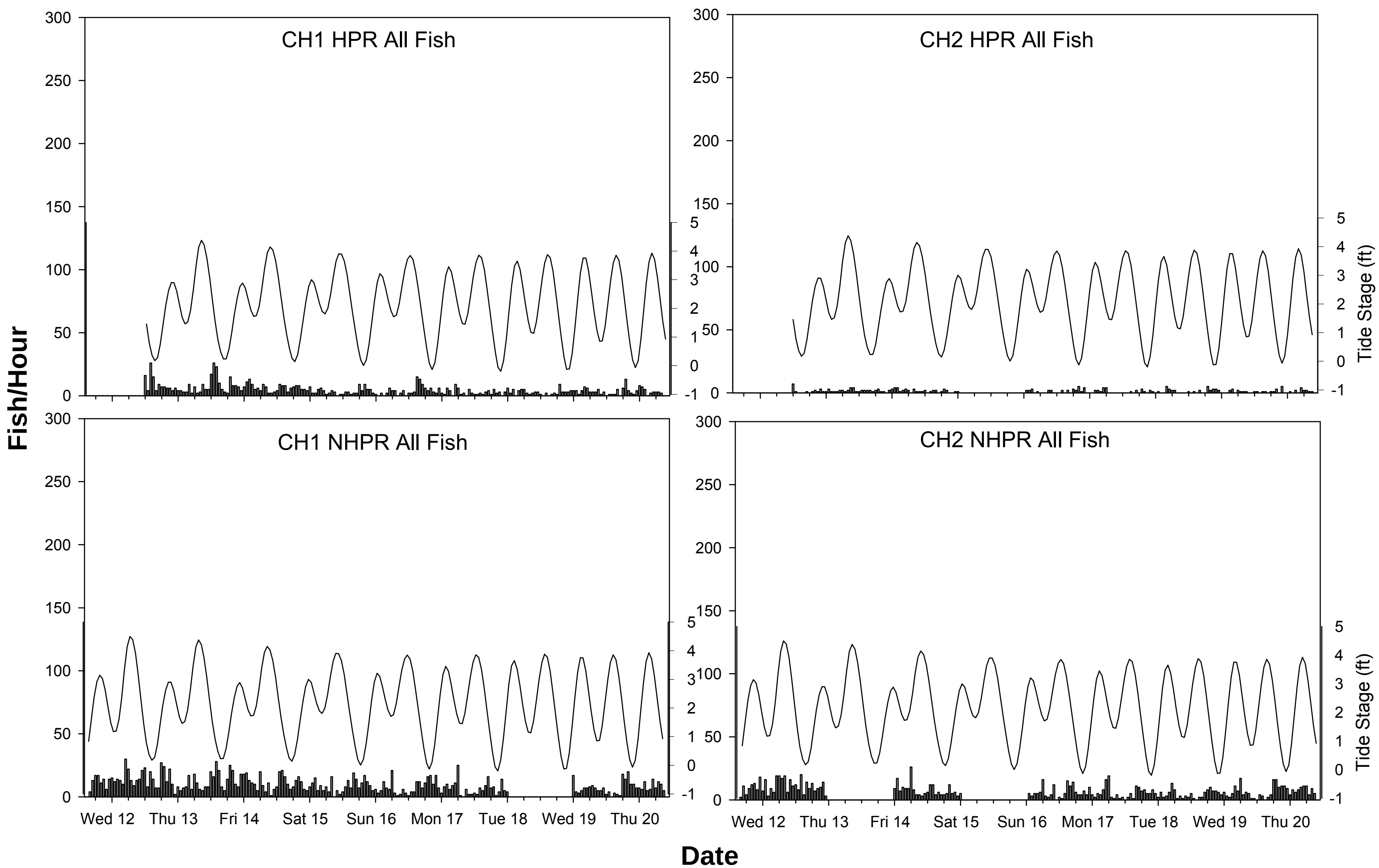


Figure 57- March 2008 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

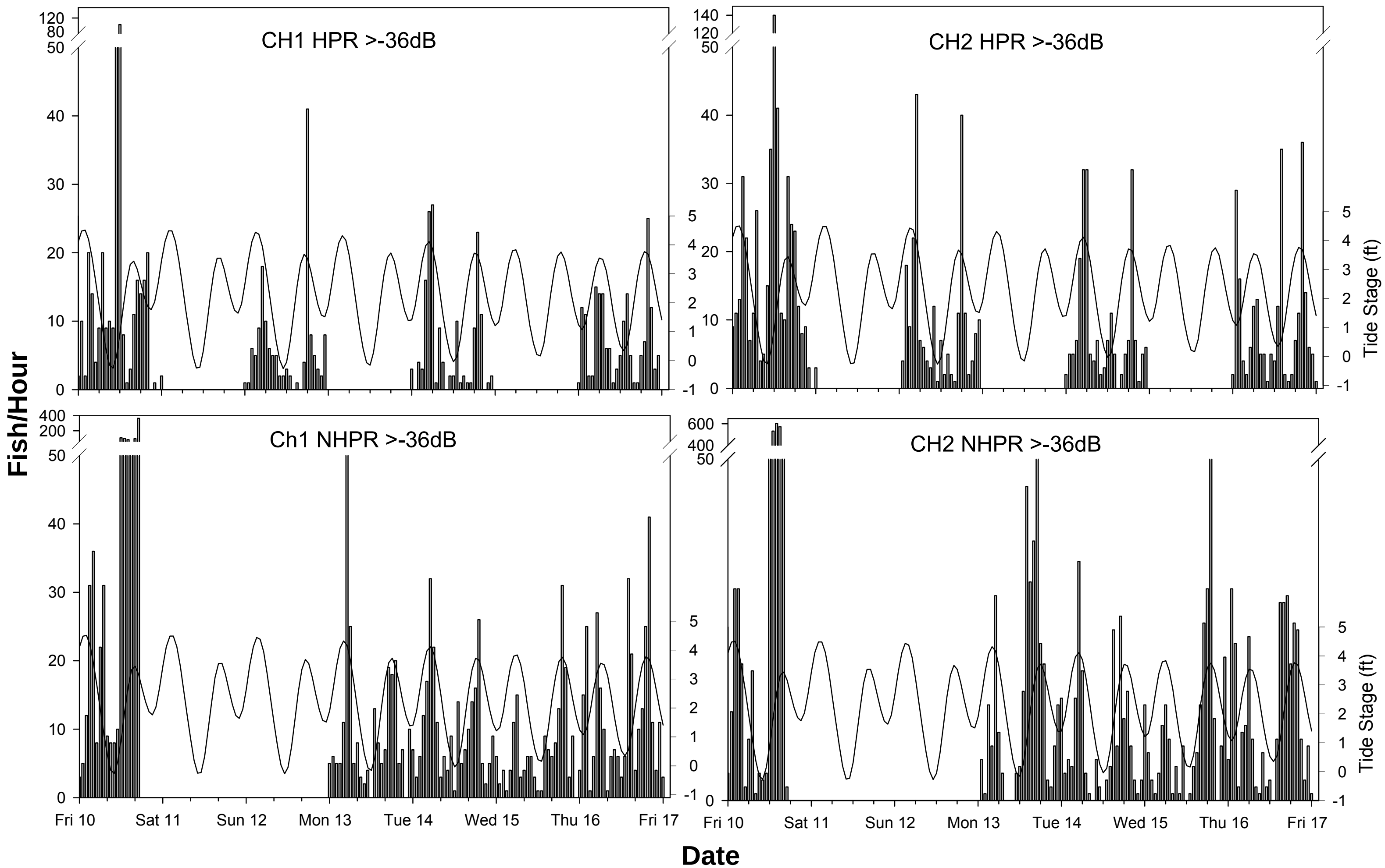


Figure 58- August 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

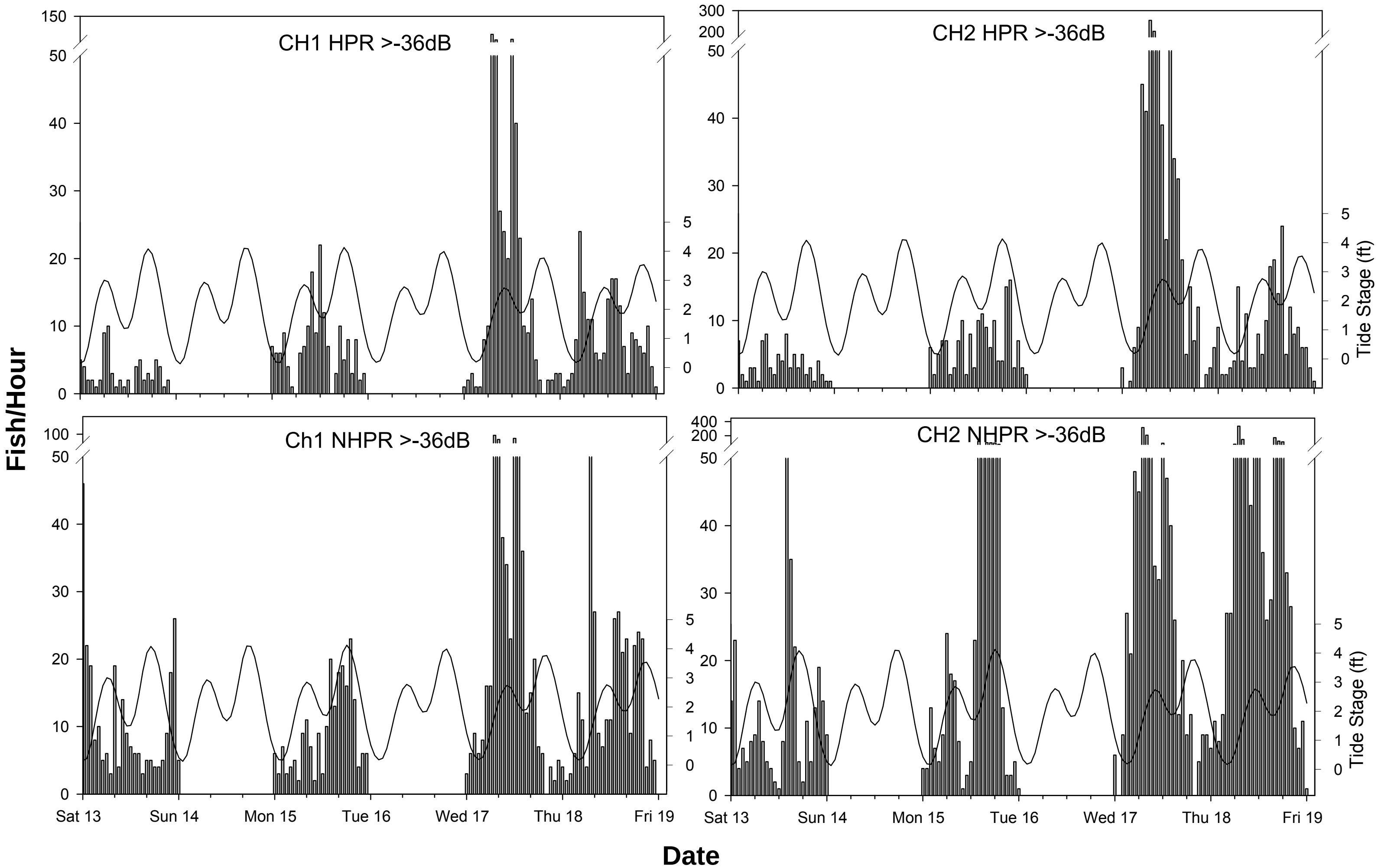


Figure 59- October 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

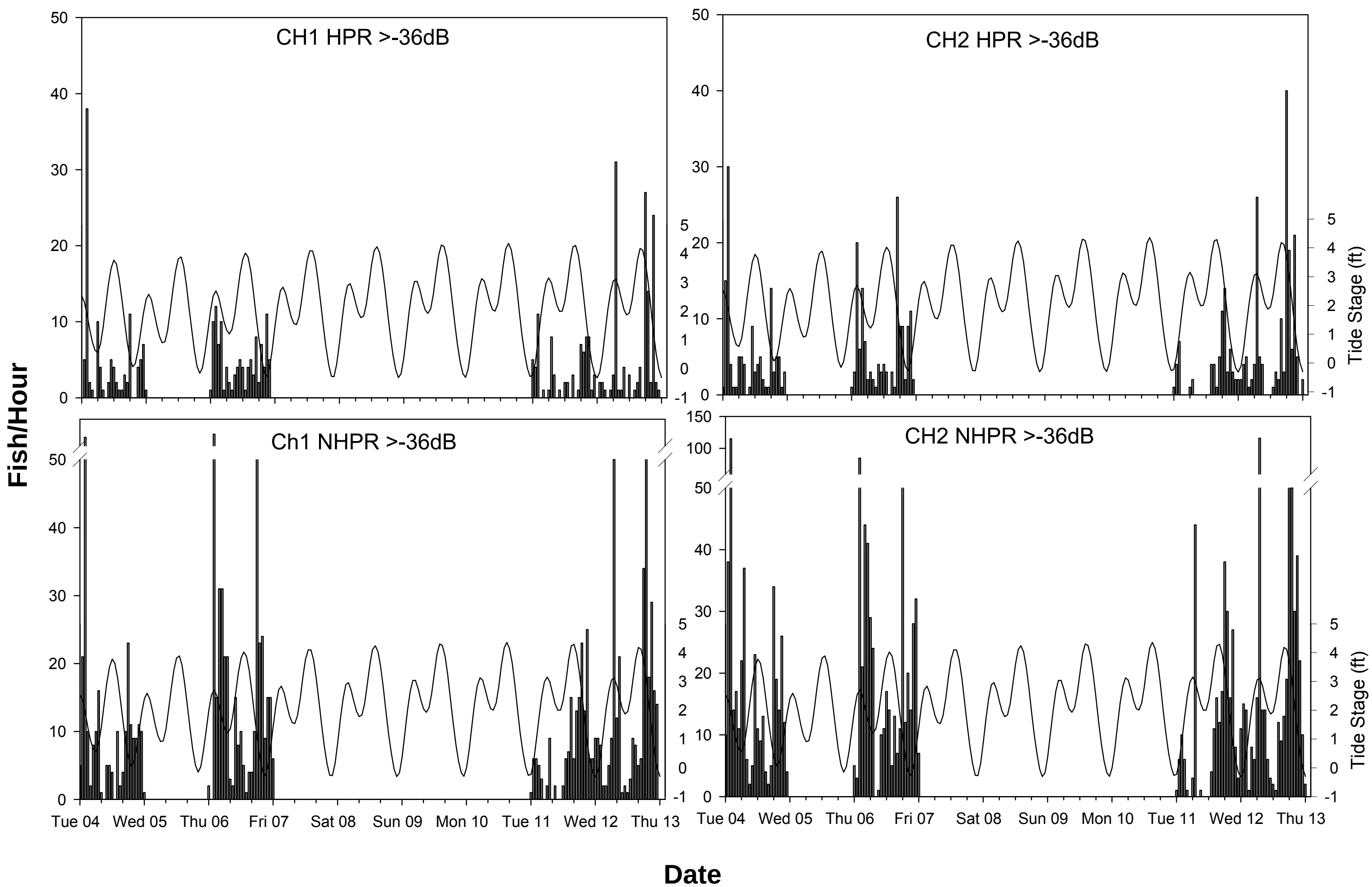


Figure 60- December 2007 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

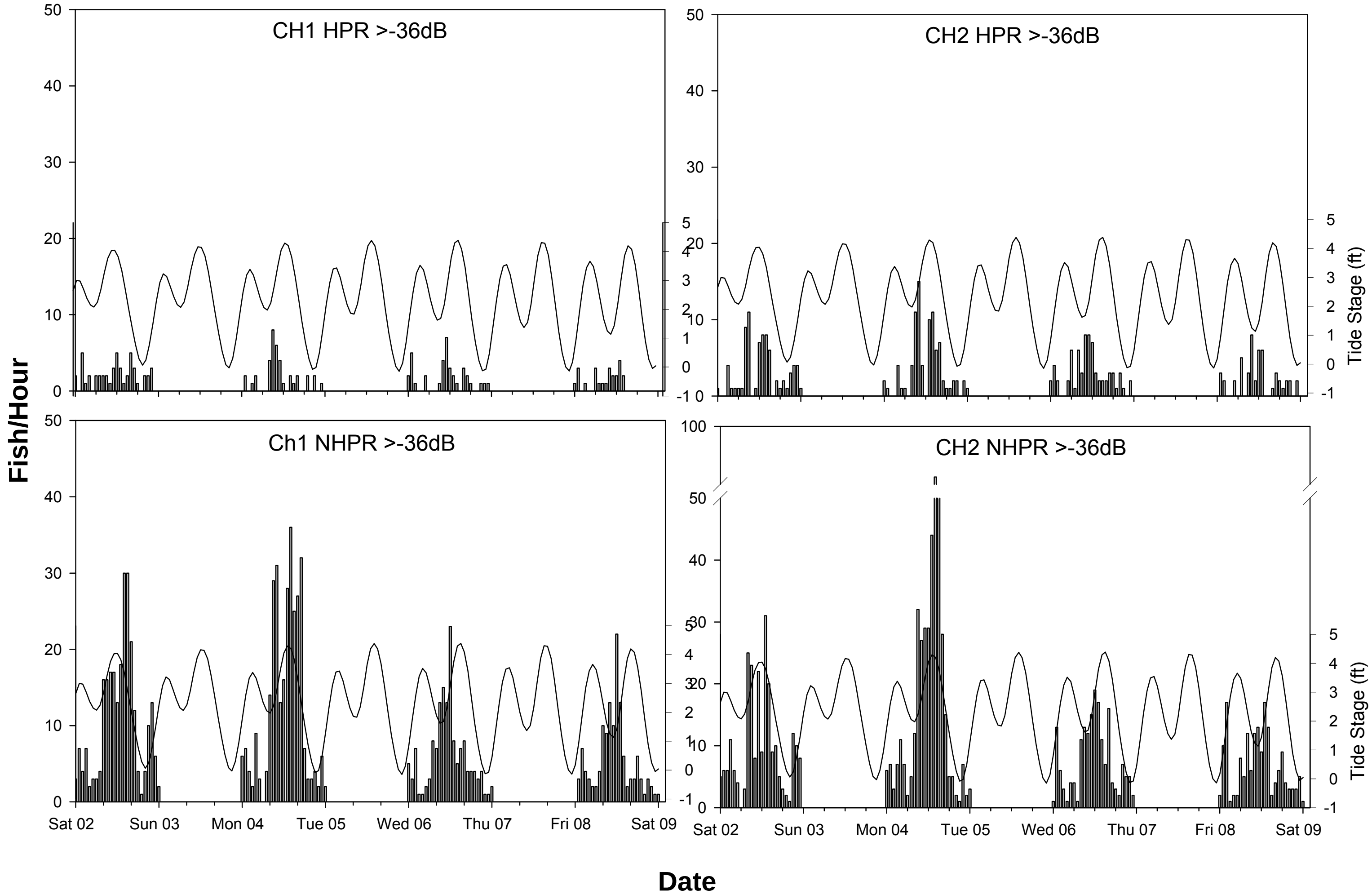


Figure 61- February 2008 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

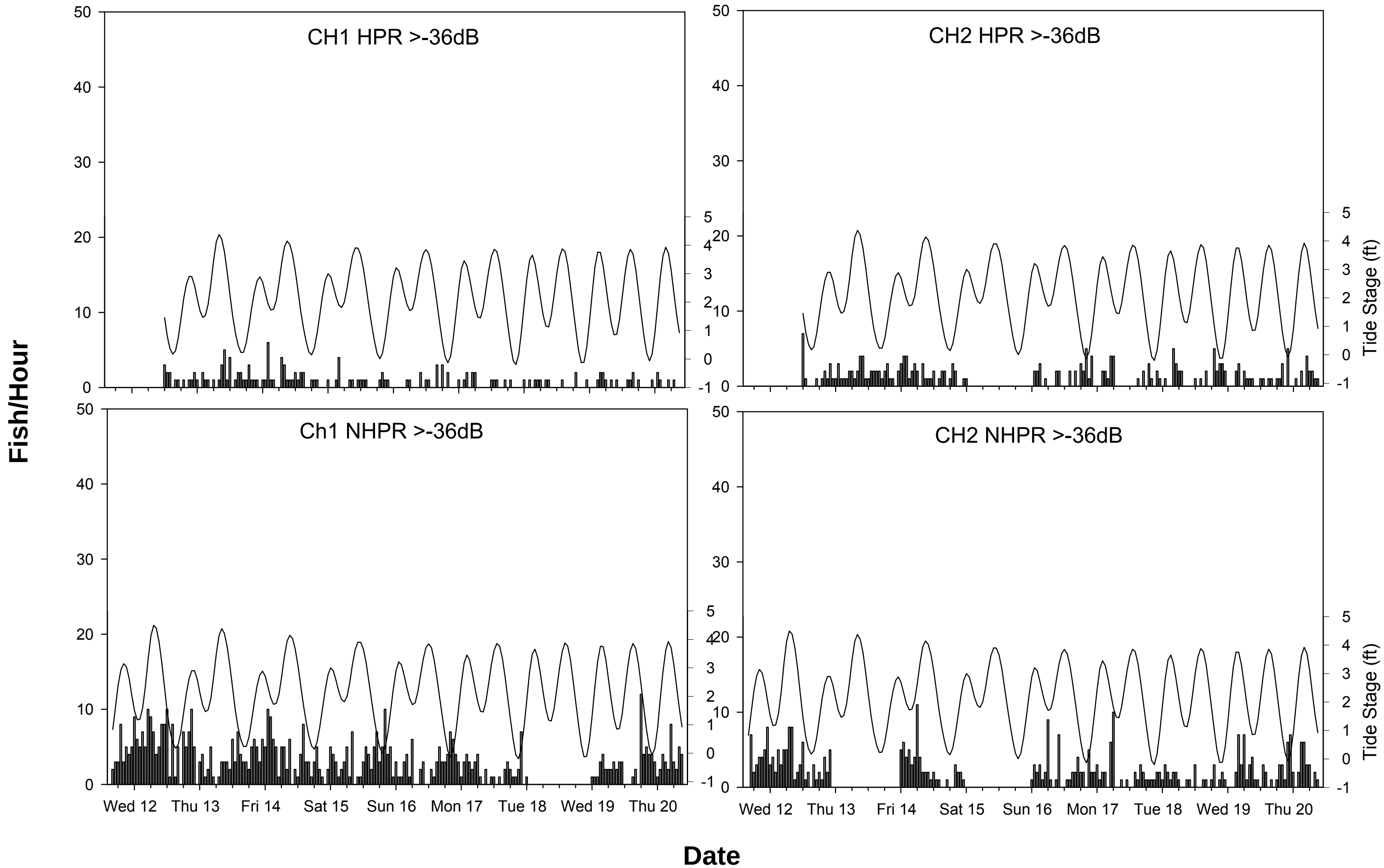


Figure 62- March 2008 fixed site releases, number of fish/hour observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

The apparent strength of the response in fish activity/movement was lower for each of the two latter dates in August. On both these days, however, fewer than half the numbers of fish were released each time than during the August 10 release. However, being several days later, the phase of the tide had shifted forward several hours, which may have impacted our ability to observe the fish. On August 13 and 15 fish were released on an incoming tide whereas on the August 10 it was closer to the peak of the tide. The tidal influence on fish observations may be a function of the direction and strength of flow in the channel. The transducer array sits on the downstream side of the release pipe. On a strong outgoing tide fish tend to congregate on the downstream side of the release pipe, which puts them nearly in front of the transducers. On a strong incoming tide, currents are neutral to slightly upstream. At these times fish are located more directly in front of or slightly upstream of the release pipe and can at times be outside of the zone of detection for the transducers. During October, the pattern was similarly strong and it appears releases were associated with an increase in activity. This was also supported by DIDSON observations.

Changes in apparent fish abundance in front of the transducer array also appear independent of any release. During August and October, this change in abundance is probably a result of the resident group of fish moving their location in front of the release pipe in relation to the tide. DIDSON camera observations indicate that for August and October a large resident group of fish remains at all times in front of the release pipe, this is likely because releases are regular and large enough that fish are conditioned to remain in the area. Such an effect has also been noticed where hatchery trucks stock fish on a regular basis. Fish can learn when “feeding time” is going to occur. While the release may not always occur daily at the release site, the releases occur often enough to keep fish attracted to the area. February still has some fairly well defined peaks of fish indicating some fish may still be remaining in the area, however, by March this pattern is not apparent. March also coincides with lowest numbers of fish being released, and the lowest populations observed in either the release or two control sites.

Graphical data showing all fish, and just fish larger than -36 dB (~25 cm [9.8 in]), show similar trends of increased fish activity. This can mean one of several things; first, some of the fish exiting the release pipe are probably being detected; second, there are probably some smaller predatory fish feeding in the areas as well; and third, and most importantly, the size break we used assumes a fish optimally oriented towards the transducer. If fish are actively moving around back and forth near the transducers their orientation will be constantly changing. What appears as a -32 dB fish in one frame, may be represented as a -40 dB fish in the next frame simply due to orientation. This is not as big a problem in the mobile surveys, particularly with downlooking data where the transducer has a higher probability of seeing a fish in proper orientation most of the time. Even with this orientation issue, there still is a bi-modal distribution of fish observed by the transducers (Figure 63); however, a lot of the smaller targets may also represent larger fish.

By focusing on the larger targets, numerous valid fish may be rejected, but there is also less likelihood of including small fish that happen to be in the vicinity and were observed. This effect would result in any population estimate being biased on the low side, but for behavioral purposes, it might be best to avoid smaller targets. Following release times, fish appear to crowd closer to the location of the release pipe in both August and October, however, during December, February and March, there are so few fish that no real change in the distribution of targets within the receiving water is detected (Figures 64–73). This decrease in range may be correlated to the location of the fish holding in the area as well. On an outgoing tide fish tend to congregate more on the downstream side of the release pipe, and nearer the zone of observation for our system, therefore, part of the decrease in range observed could be a result of this shift in the location of the fish school. Of note, during August and October, the largest pulses of fish observed are also associated with the closest average range measured for a given hourly interval. During February the average range (target distance from transducer) is well out away from the transducers and therefore is more likely to represent activity changes for fish in the open water zone of the channel.

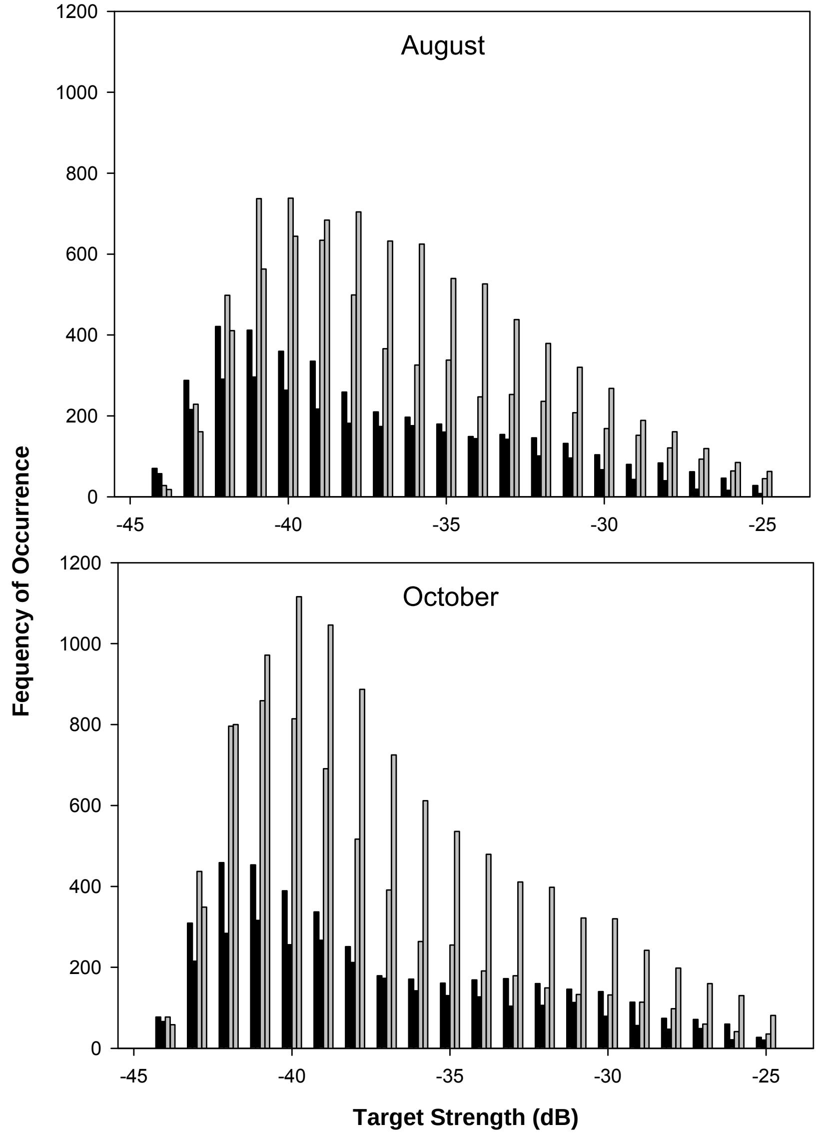


Figure 63- Histogram of fish sizes from fixed station transducers for August and October. Black bars are CH1 and CH2 HPR, gray bars are CH1 and CH2 NHPR. A target strength of -45 dB equals an approximately 9.5 cm (3.7 in) fish while a strength of -25 dB equals an approximately 110 cm (43.3 in) fish.

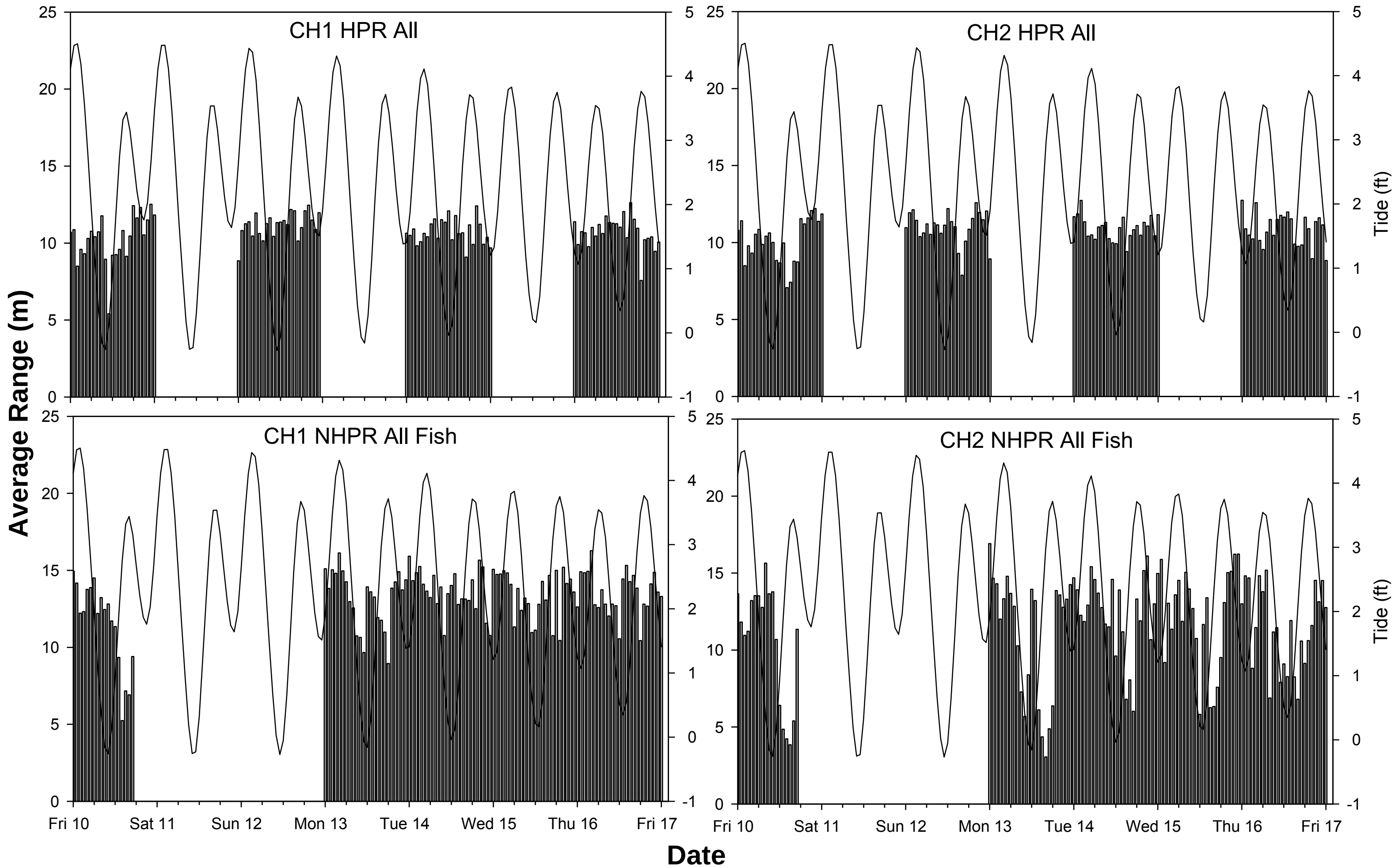


Figure 64- August 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

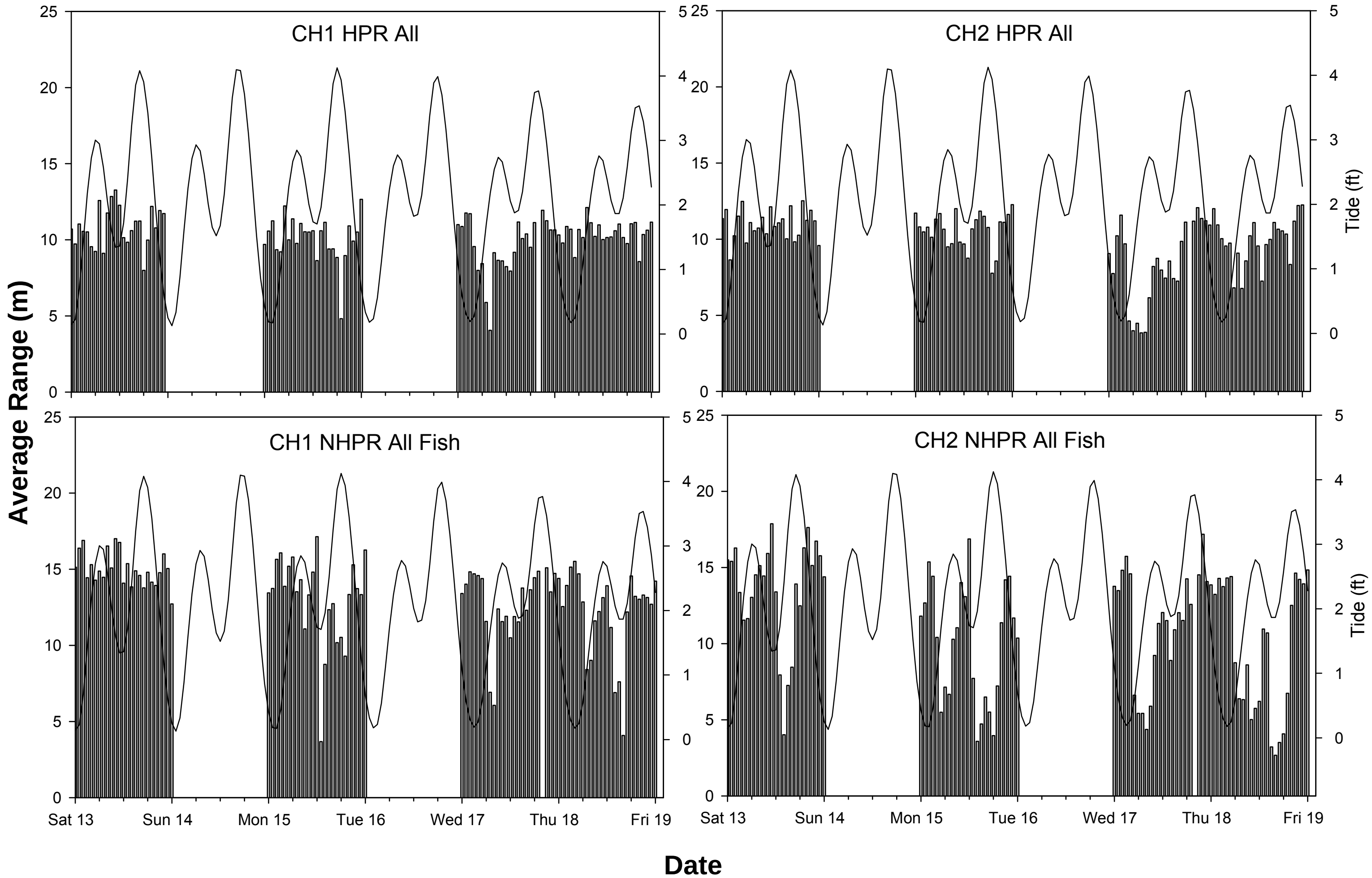


Figure 65- October 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

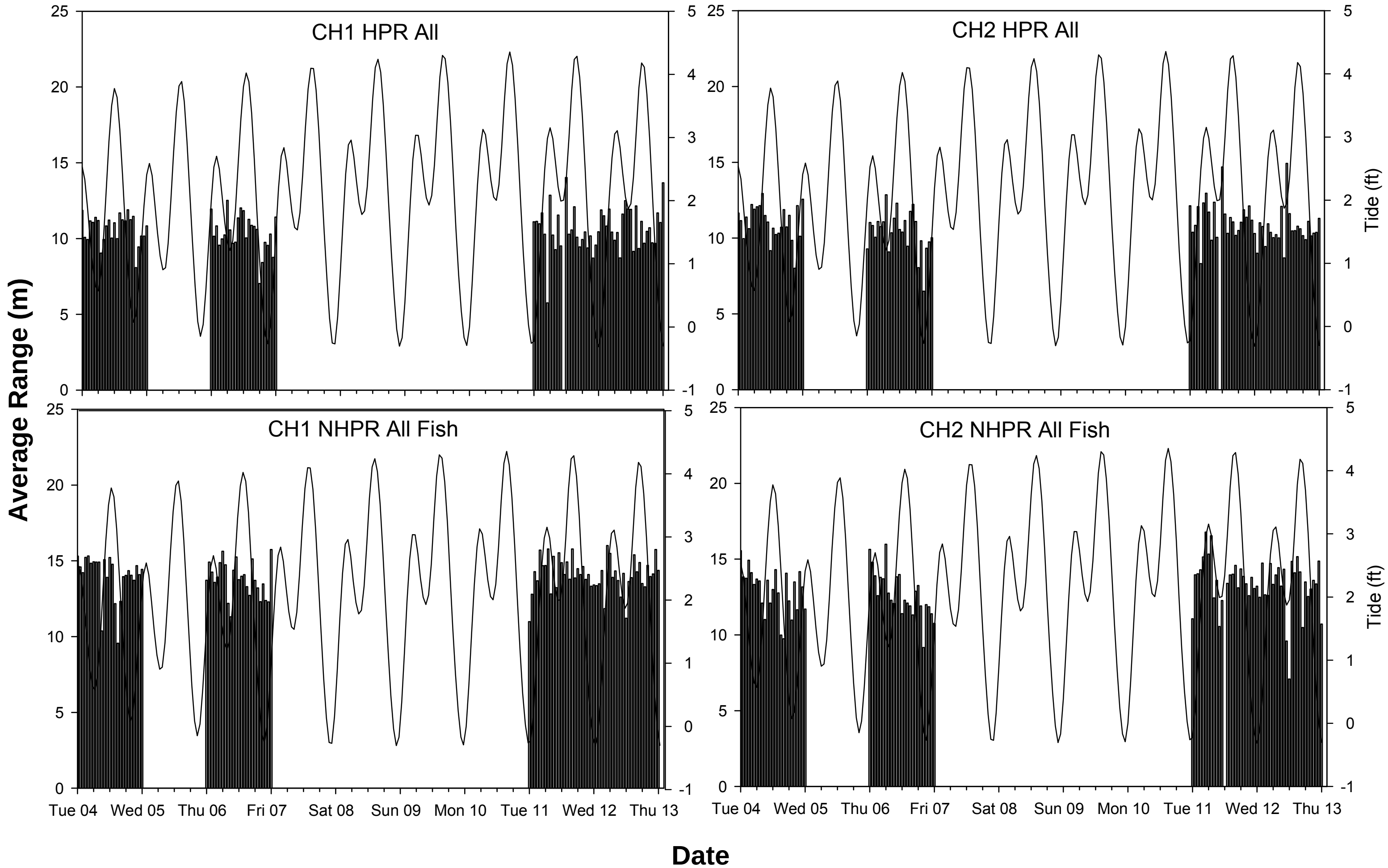


Figure 66- December 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

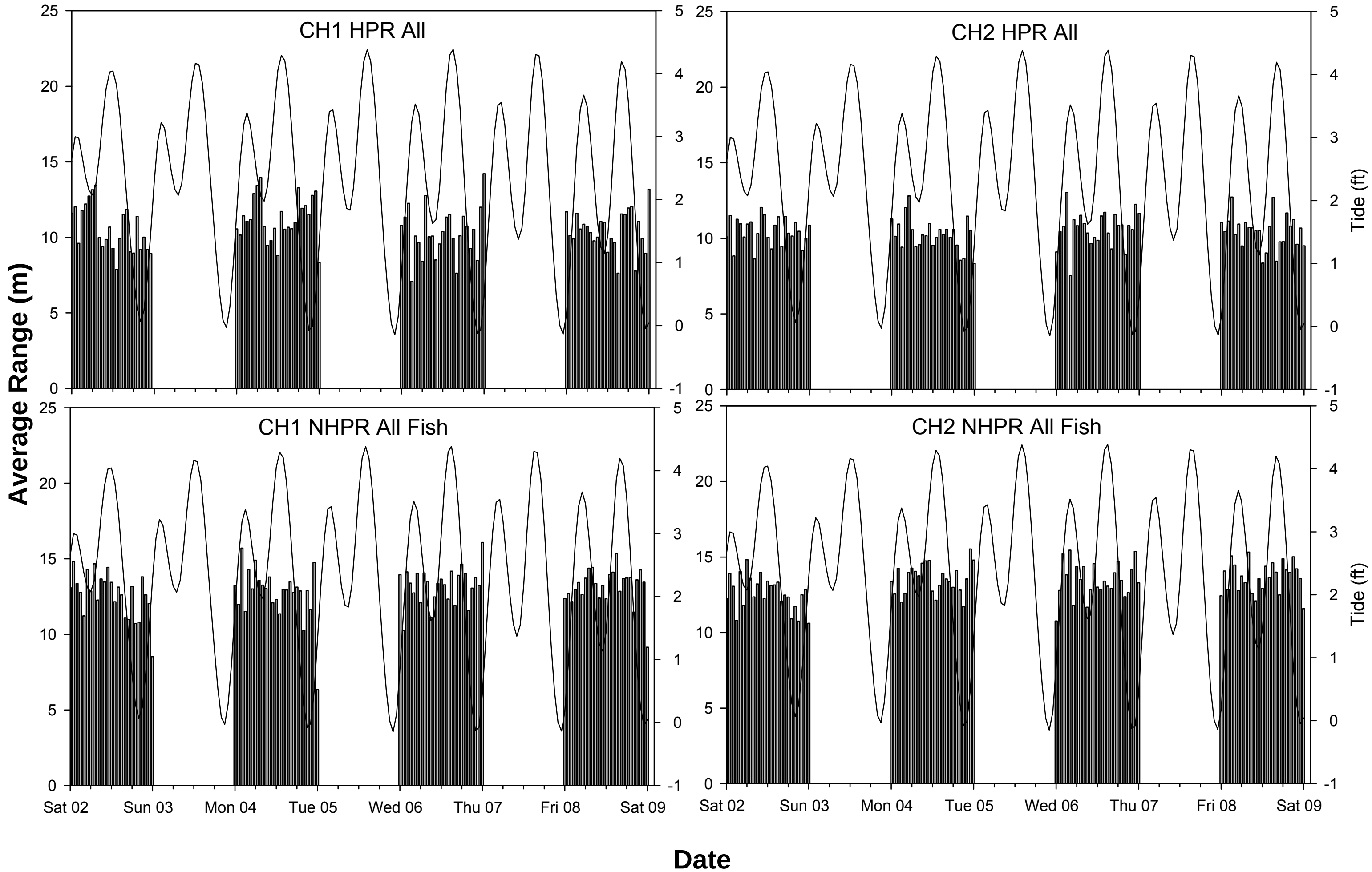


Figure 67- February 2008 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

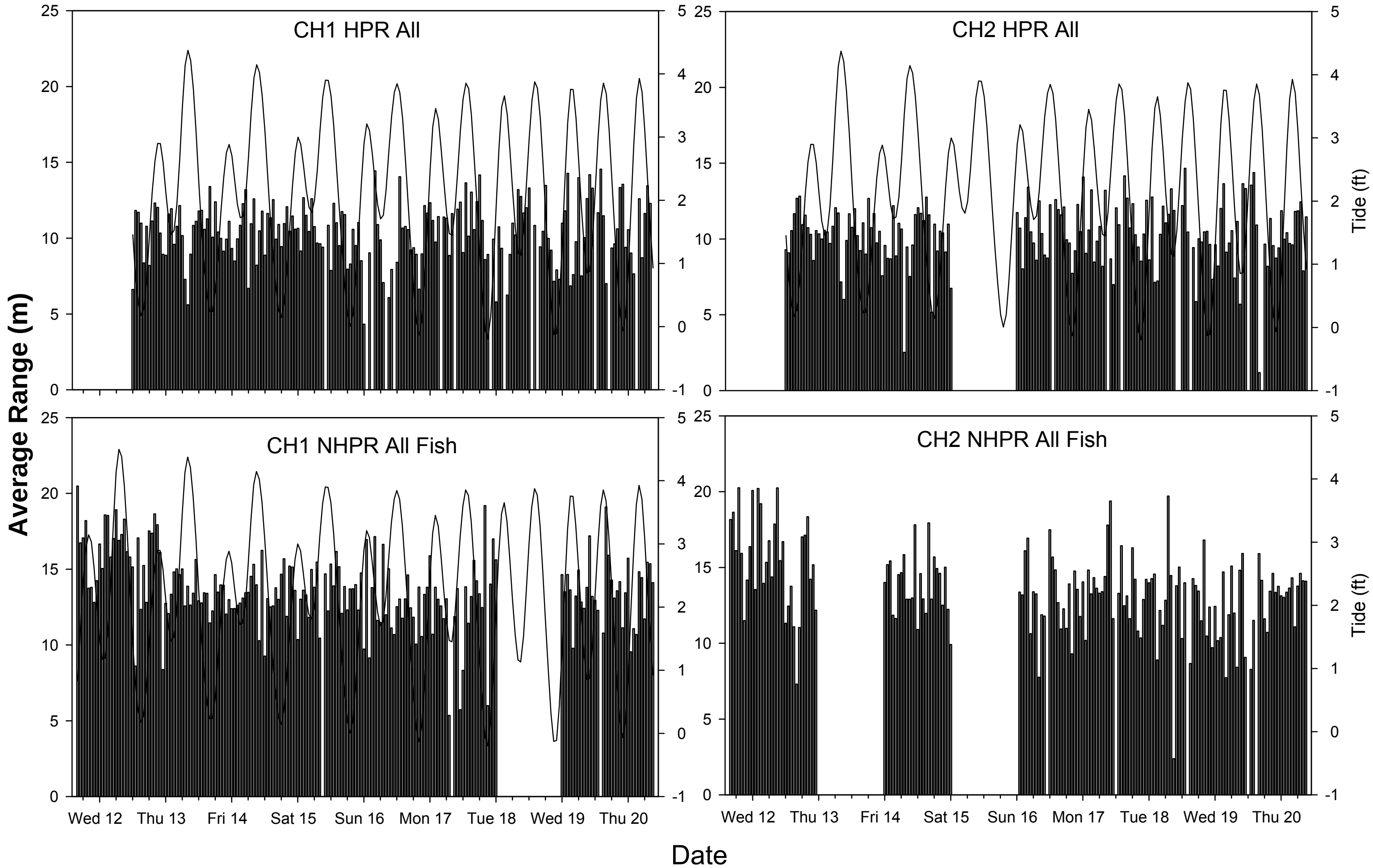


Figure 68- March 2008 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -45 dB or 9.5 cm (3.7 in).

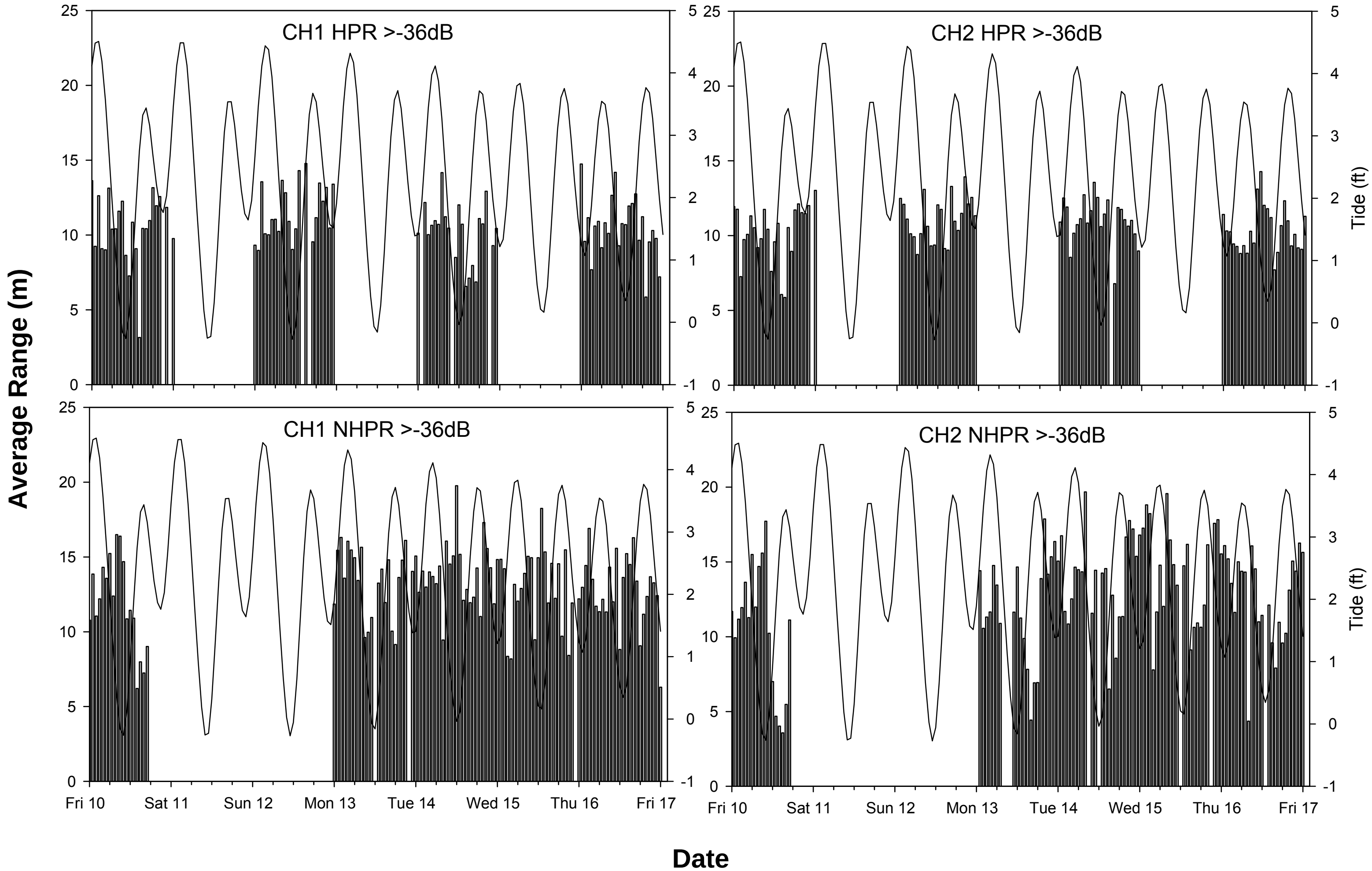


Figure 69- August 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

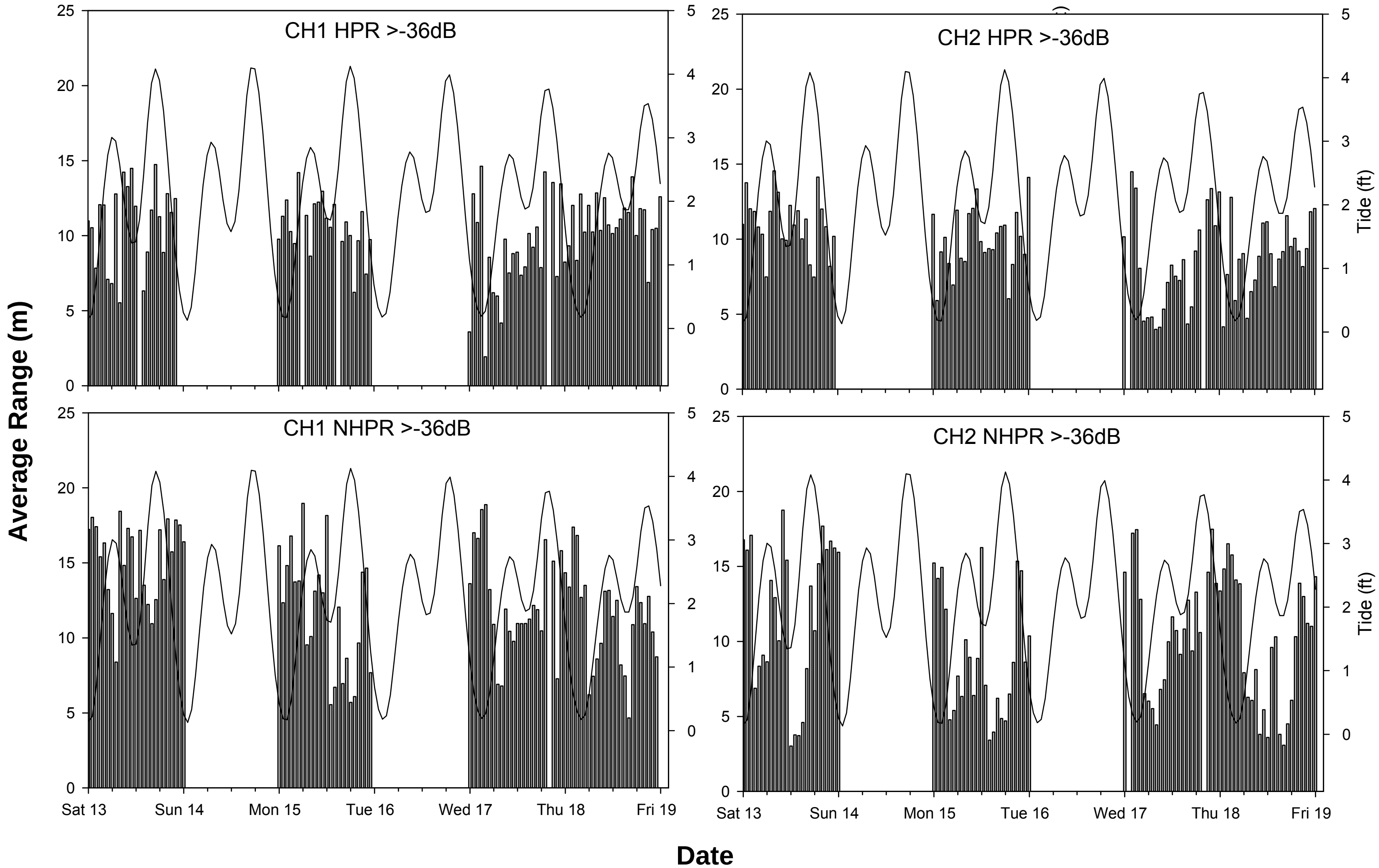


Figure 70- October 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

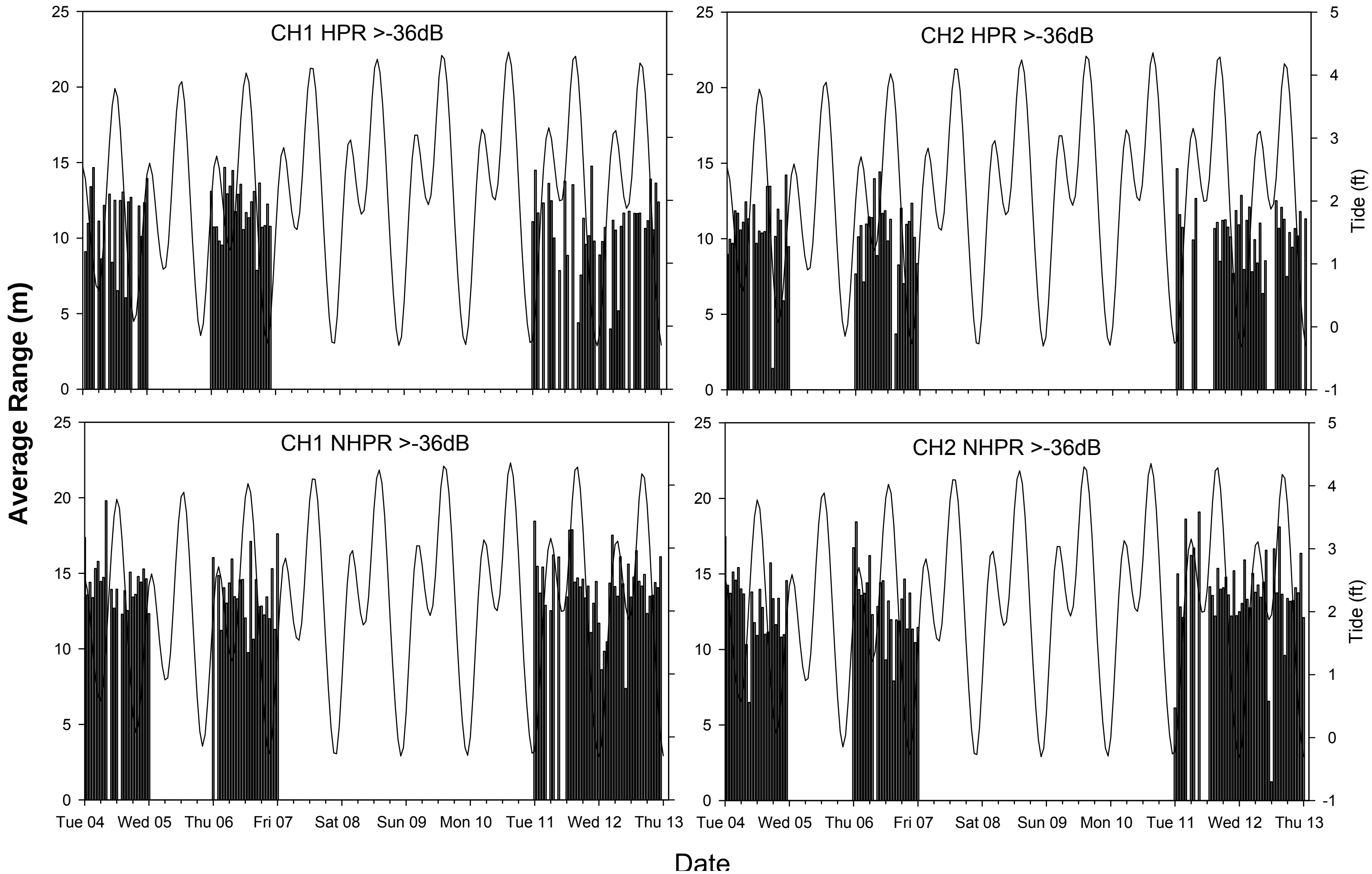


Figure 71- December 2007 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

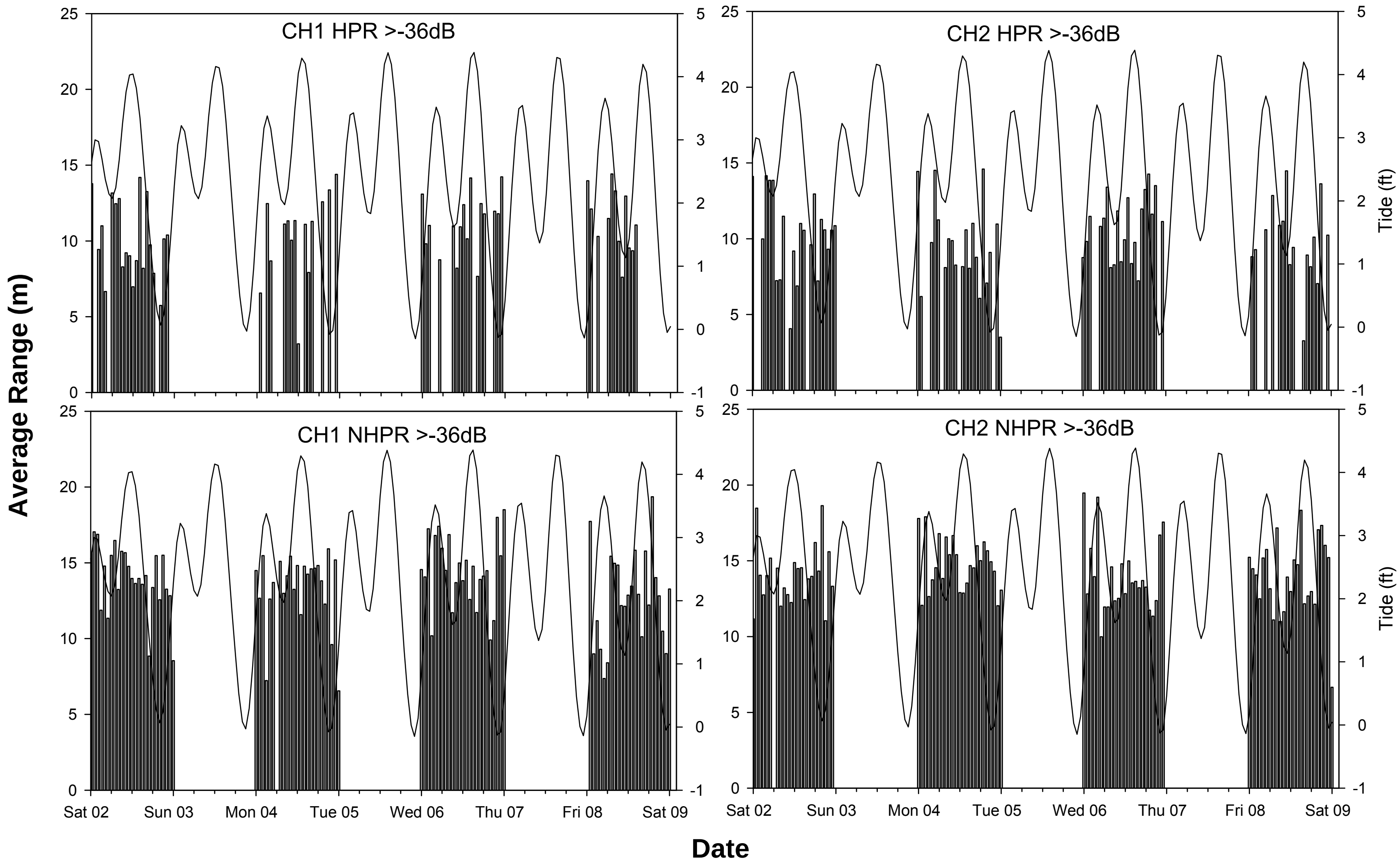


Figure 72- February 2008 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

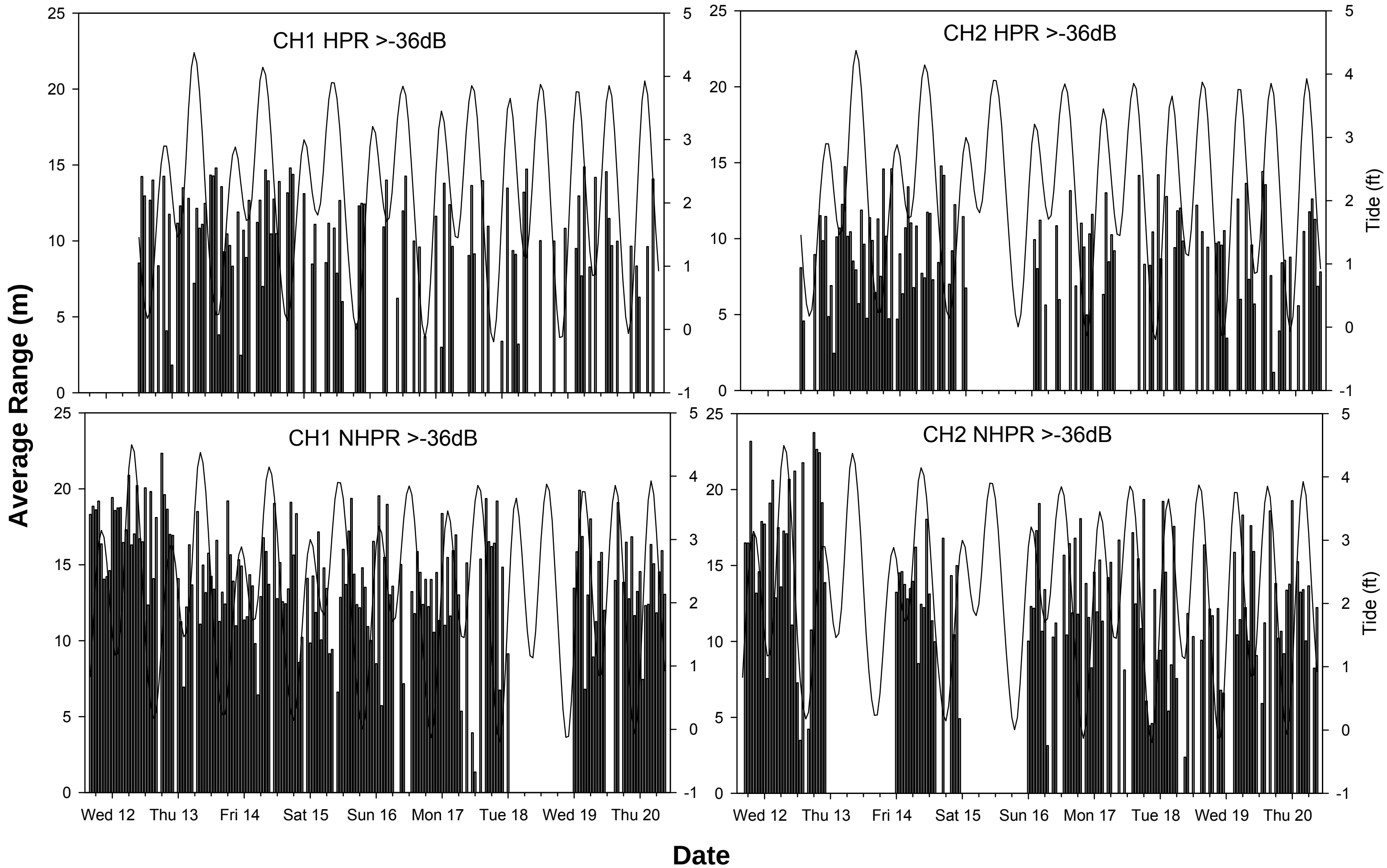


Figure 73- March 2008 fixed site releases, average range from transducer of fish observed at release site. Data presented is for all fish larger than -36 dB or 25–26 cm (9.8–10.2 in).

5.2.3 Bioenergetics

Predation as estimated by an energetics approach is at best only an indirect preliminary estimate of the true predation mortality experienced by fish following their release. However, an energetics approach does provide a good starting point to determine what the magnitude of predation might be. In this model only the average fish are used, there is a slight skew towards smaller fish based on the difference between the median and average values of predators in the river reach. The average size predator as determined acoustically was 36–40 cm (14.2–15.7 in); the median value was slightly smaller at 33–36 cm (13–14.2 in) (Figure 63, Table 20). These values were used as an average size predator, based on literature reported size ranges for each species. Many parameters in the model could impact the overall estimate of predation. The conservative approach presented here would put bounds on the lower limits of predation in the reach.

Table 20- Average size of fish when cutoff is at -36dB for both mobile and fixed station.

Fixed station

Month	Average Target Size	Median Target Size	Num Fish	Average Fish Length (cm)	Median Fish Length (cm)
August	-32.12271	-32.792124	3172	39.4	35.9
October	-31.63473	-32.286958	3593	41.2	38
December	-32.80897	-33.4686255	1711	35.9	33.3
February	-32.86817	-33.604939	1003	35.9	32.8
March	-31.8856	-32.81692	375	40.3	35.9

Mobile Surveys

Date	Down Looking Average Target Size		Date	Side Looking Average Target Size
08/15/2007	-25.00745	n=4	08/11/2007	-32.09790418
08/16/2007	-33.67473		08/13/2007	-33.04348976
08/17/2007	-28.81555		08/14/2007	-30.56966388
10/13/2007	-29.56245		10/13/2007	-31.22754548
10/14/2007	-32.63714		10/14/2007	-31.49582121
10/16/2007	-31.6676		10/16/2007	-31.67973421
10/17/2007	-32.56465		10/17/2007	-31.44935489
10/19/2007	-28.91075		10/19/2007	-32.89688435
12/03/2007	-32.32749		12/03/2007	-31.9461426
12/04/2007	-31.90242		12/04/2007	-32.71206354
12/05/2007	-32.14662		12/05/2007	-31.30880272
12/06/2007	-33.74409		12/06/2007	-32.82576671
12/10/2007	-32.58633		12/10/2007	-32.08910888
12/11/2007	-32.02542		12/11/2007	-32.45410551
12/12/2007	-32.12074		12/12/2007	-33.07093023
02/02/2008	-31.27591		02/02/2008	-32.51561264
02/03/2008	-32.19827		02/03/2008	-32.10073808
02/04/2008	-31.49128		02/04/2008	-32.67942268
02/05/2008	-30.41288		02/05/2008	-32.08486758
02/06/2008	-29.6741		02/06/2008	-31.80554794
02/07/2008	-31.05055		02/07/2008	-32.78003863
02/08/2008	-30.5913		02/08/2008	-32.63821656
02/09/2008	-31.46211		02/09/2008	-32.38522632
03/11/2008	-33.03666		03/11/2008	-29.20937507
03/12/2008	-32.47424		03/12/2008	-32.48826699
03/17/2008	-32.94173		03/17/2008	-32.15747523
03/18/2008	-31.67701		03/18/2008	-30.18602817
03/19/2008	-32.24283		03/19/2008	-30.87523469
			Grand Average	-32.03043919

Of the three predatory species present predation by striped bass has the potential to have the greatest impact on fish at the release site based on average consumption requirements for each species (Figures 74 & 75). For all three species modeled there is a temperature dependent shift in consumption rates, with highest rates occurring in mid-summer. Striped bass show the longest period of time of high consumption, while largemouth bass have the shortest, due to differences in temperature tolerances and preferences between the species.

To convert consumption rates to a per fish and whole population estimate, average weight of each species based, on acoustic size, was calculated using the following length weight relationships: For striped bass $W = 0.0066*(L^{3.12})$ (Kimmerer and others 2005), for pikeminnow $\log W = 3.12 \log L - 5.32$ (Tucker and others 1998), and for largemouth bass $W = 3.2*L-5.35$ (Wege and Anderson 1978), where weight is in grams and length is in mm. Assuming an average predator length of 38 cm (15 in), a striped bass should weigh approximately 560 g (1.2 lb), a pikeminnow, 593 g (1.3 lb), and a largemouth 1,210 g (2.6 lb). These numbers are only approximate, as the different body morphometries between the species will impact the acoustic size. Both pikeminnow and striped bass have similar body forms at this size, however largemouth tend to have a much deeper body, and may be biasing the acoustic estimate. Based on average size, at peak consumption striped bass consume the greatest amount of prey on a daily basis followed by largemouth bass, then pikeminnow. Largemouth have the lowest per gram prey requirement, but because of their size total consumption is higher (Figure 75). Figures 76–78 provide an estimate of total population consumption based on population densities as determined using mobile surveys for the SWP Horseshoe Bend release site and two control sites.

Growth rates of individuals near the release pipe outlet may be different from those anywhere else. The data presented is based on average growth rates, indicating fish feed at some percent below their maximum consumption rates. Since fish are opportunistic feeders and the model suggests that on average these species are feeding well below their maximum consumption rates, adjusting this rate in the model can allow exploration of the potential impact of these species if they feed at or near their maximal rate. In the bioenergetics model, the proportion of maximum consumption is adjusted through the use of the p-value, which can be viewed as the amount of food available in a given area of habitat. Average fish growth in this model resulted in p-values for striped bass, largemouth bass and pikeminnow of 0.36, 0.34, and 0.41 respectively. In the case of the release site where large pulses of food items may be entering the water column, a more realistic approach would be to examine a broad range of consumption rates, in this case varying the p-value to look at the potential for consumption given a locally increased availability of food (Figure 79). What constitutes a maximal consumption rate in this field situation is unknown. Also, no assumptions about activity patterns in these fish are made and not doing so will tend to bias the model downward in terms of potential predation effects.

Based on the average p-value calculated by the model the average striped bass probably consumes around 12g/day (0.026 lb/day), or about 2% of its body weight to achieve the average growth observed in the delta. Fish are opportunistic predators however, and given a food source they will consume far greater than this amount. Depending on the time of year, a striped bass nearing maximum consumption rates, may be consuming two or more times this amount of food (Figure 79). Near the release pipe, fish are likely feeding opportunistically and will consume as much food as they can when it is available. Assuming a striped bass is feeding in this mode, the average fish would be expected to consume on the order of 18+ g (0.04 lb) of food per day in August and October. For every 100 striped bass at the release site on average they could consume about 1.8 kg (4 lb) of biomass per day. If for example 20,000 shad (or similar sized fish) were released at the SWP Horseshoe Bend release site, this would equal about 260 kg (573 lb) of biomass, assuming an average weight of 13 g (0.028 lb) for each shad. To consume 10% of the release biomass a population of about 1,450 striped bass would be needed. During October, however, when release numbers are much lower, averaging about 1,000 shad per release or about 13 kg (28.6 lb) of biomass, a very significant impact by predation on salvaged fishes at the release site would be expected.

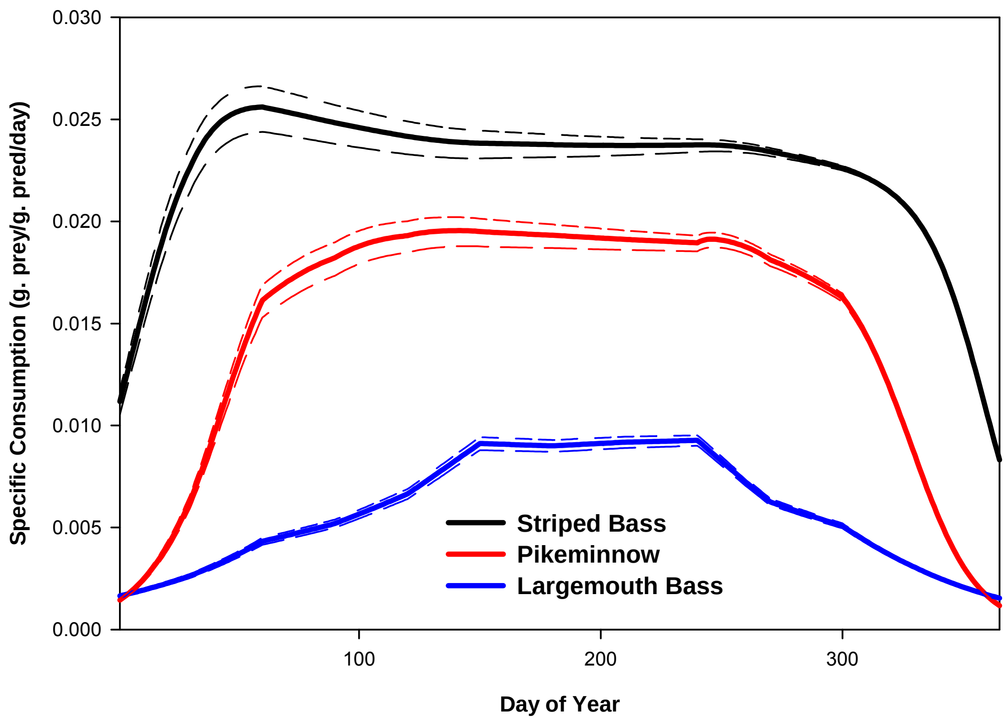


Figure 74- Daily consumption of prey as grams of prey consumed per gram of predator wet body weight. Short and long dashed lines represent the effect on consumption of a ± 30% error in annual growth rate.

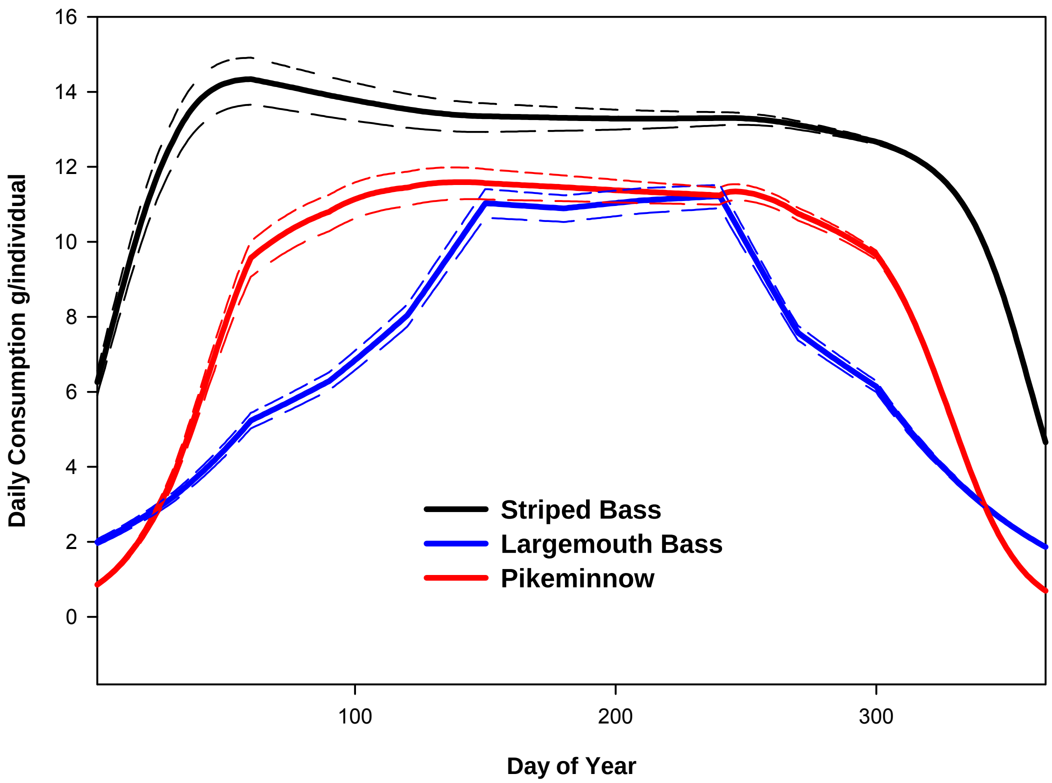


Figure 75- Daily consumption of prey as grams of prey consumed per predator species, assuming an average sized predator as determined using hydroacoustics. Short and long dashed lines represent the effect on consumption of a plus or minus 30% error in annual growth rate of predatory species.

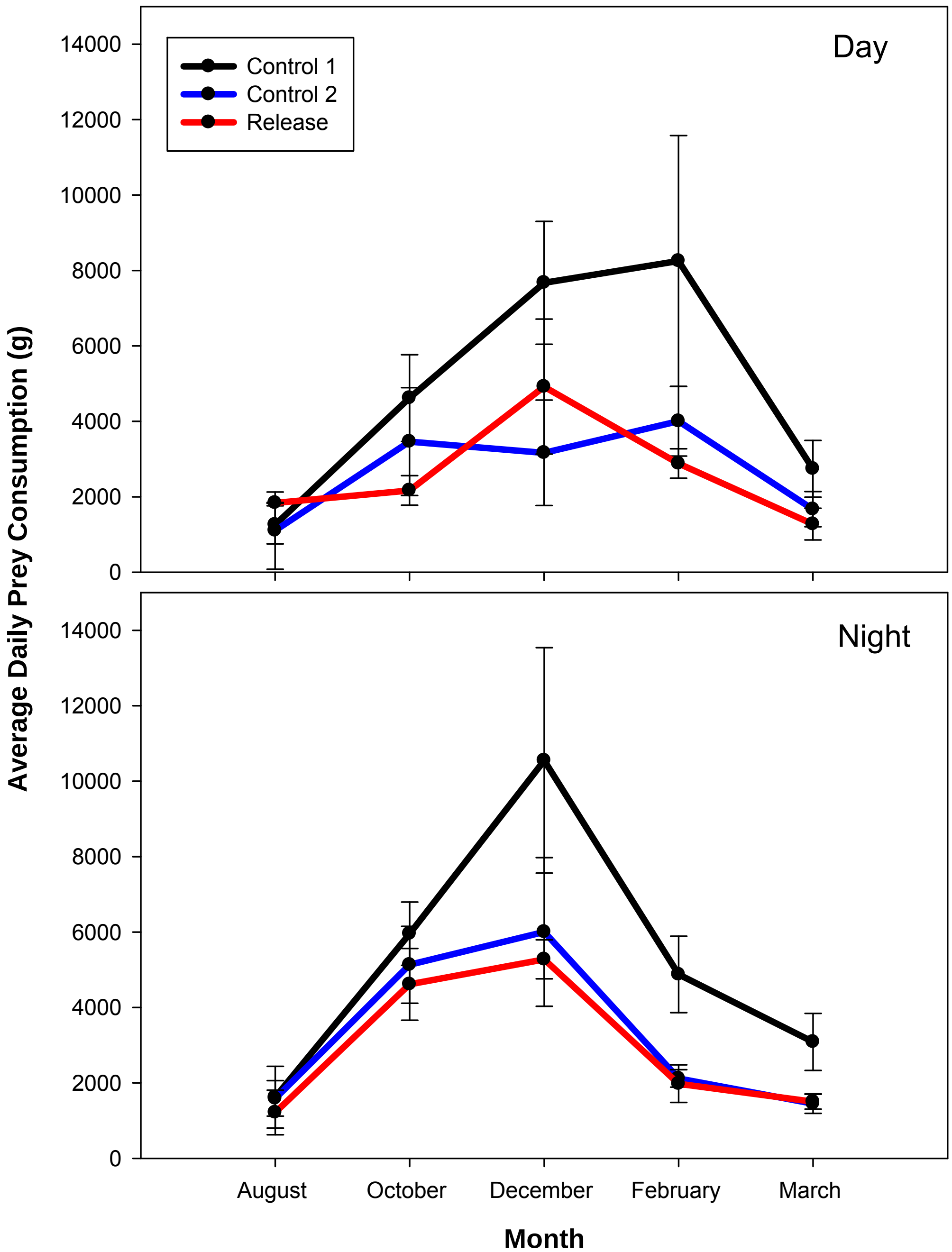


Figure 76- Estimated total daily prey consumption (g) by site, assuming striped bass comprise the population of fish greater than -36 dB (25–26 cm [9.8–10.2 in]).

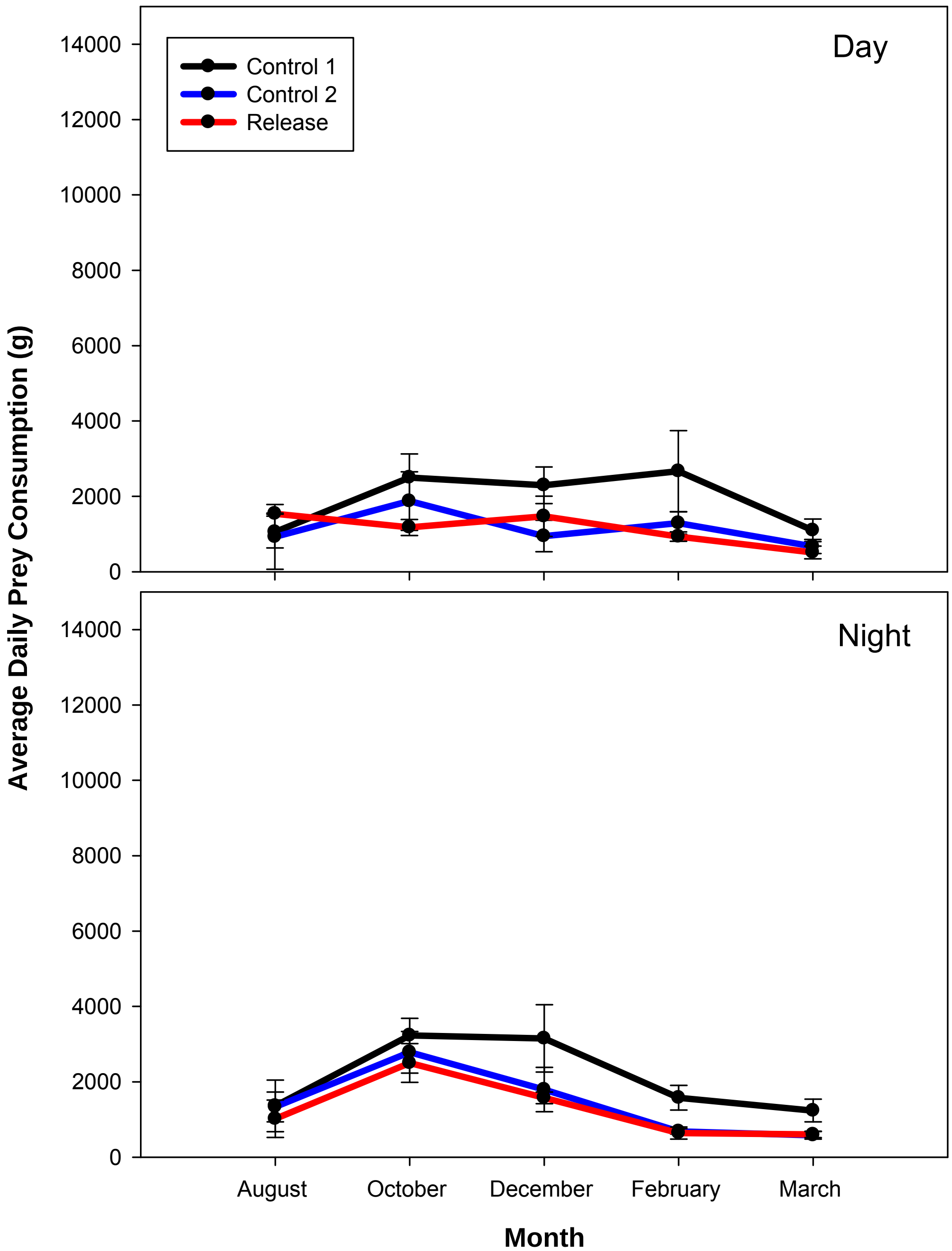


Figure 77- Estimated total daily prey consumption (g) by site, assuming largemouth bass comprise the population of fish greater than -36 dB (25–26 cm [9.8–10.2 in]).

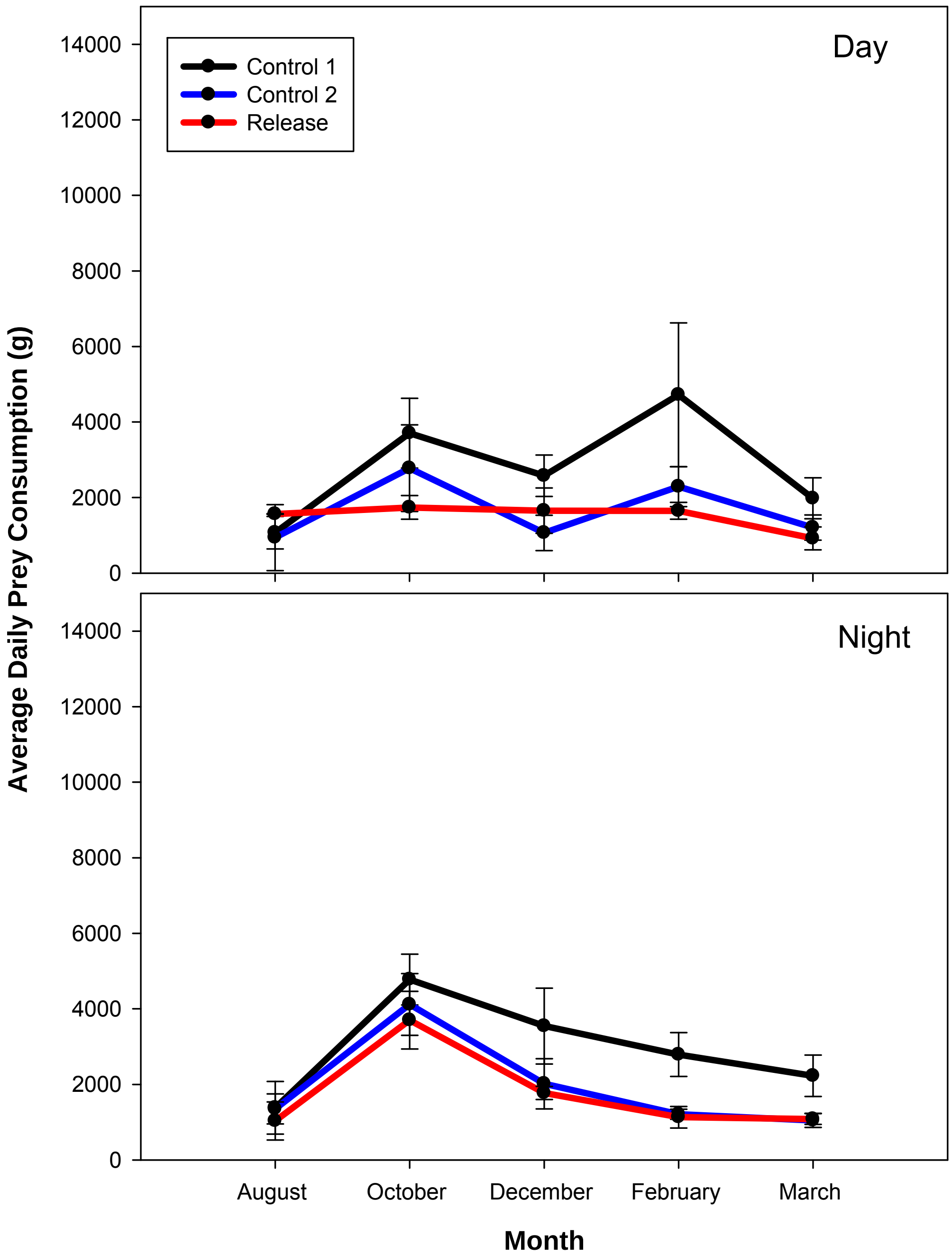


Figure 78- Estimated total daily prey consumption (g) by site, assuming pikeminnow comprise the population of fish greater than -36 dB (25–26 cm [9.8–10.2 in]).

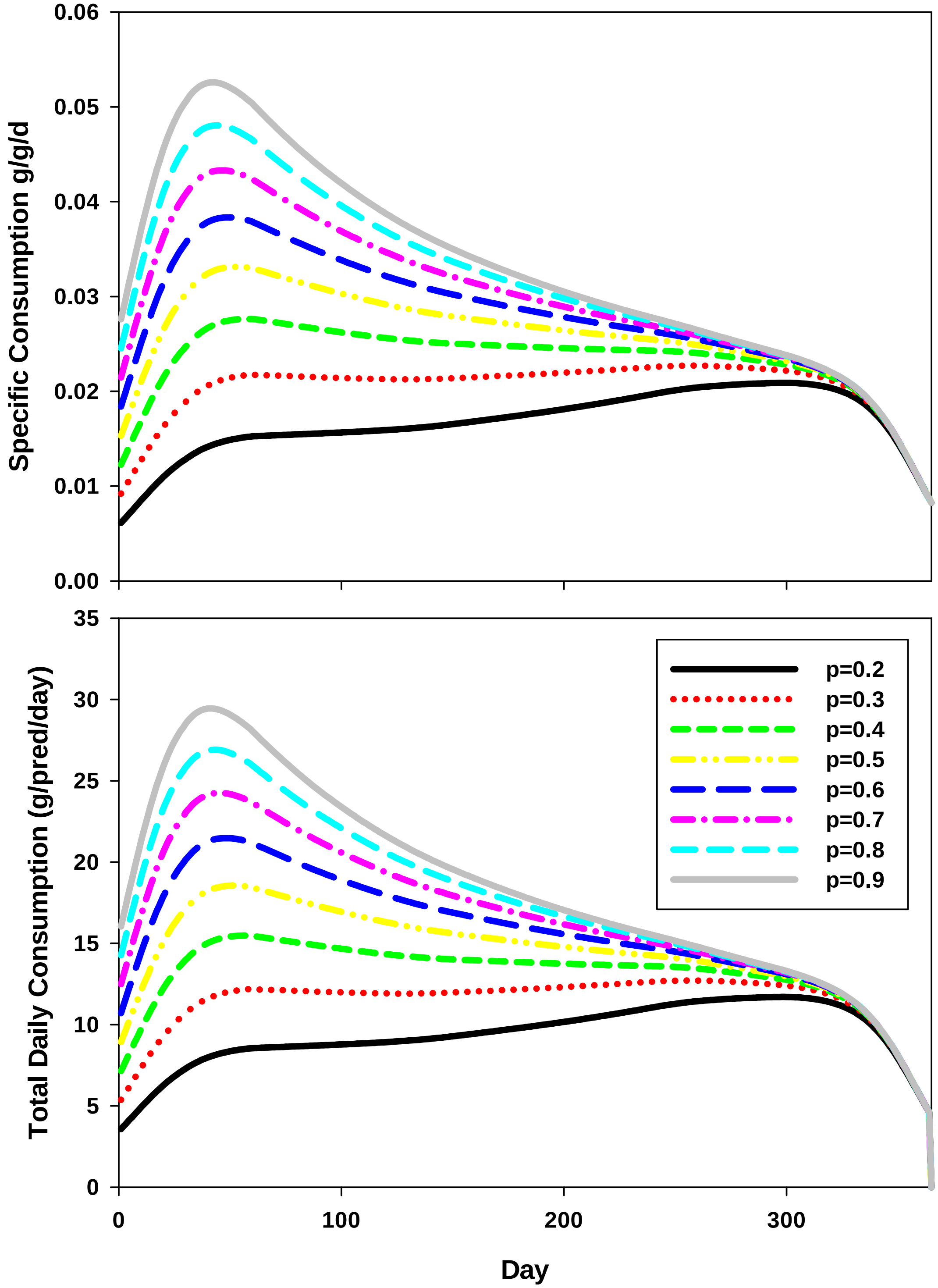


Figure 79- Changes in consumption estimates for an average 560 g (1.2 lb) striped bass in response to varying maximum consumption where the p-value is the amount of food available in a given area of habitat.

5.3 Conclusions

As was shown, predatory fish densities were in fact highest at Control Site 1, while the SWP Horseshoe Bend release site was not dissimilar from the Control Site 2. Thus, at least on the larger scale, changes in density of predators associated with the release of fish do not seem to occur. This suggests any change in predator densities is very localized and occurs at a scale smaller than that used for mobile surveys which is also supported by DIDSON observations.

At the release site there was a continual decrease in predators after the fall as the study progressed. In contrast, December saw the highest populations of fish during the mobile surveys indicating that there is seasonal variation in the density of predatory fish within the local area of the receiving waters. If the same species are being observed in each case, then it appears the predator attraction to the release site decreases faster than does the overall population of fish within the area.

It was difficult to distinguish temporal variation in the density of predatory fish in the local area of the receiving waters from release effects at times. There are times of the year when there are still strong temporal patterns, such as during February, however, since during any given season there is little temporal variability in release times, changes in the time of release cannot be determined to have any impact on predation in the area.

The data showed that fish do move in response to changes in river currents due to the tide. On average fish do tend to follow the flow, although larger fish are less likely to do this than smaller fish. Tidal variation did influence estimates of fish activity at the release site. However, depending on the direction of the current, fish may be oriented more directly in front of our transducer array, and thus numbers would appear higher, than during a tidal phase which may cause fish to orient differently in relation to the release pipe.

Activity of fish at the release site does increase greatly at times following releases, indicative of active feeding. During periods of very high numbers of observed fish, the fish were also at very close range to the transducer as indicated by a decrease in range. This shows fish are congregating near the release pipe at these times. At times of the year when predators do not appear to be congregating near the release site, no such range effect is observed. While the data collected was not sufficient for any analysis of learned behavior, the hydroacoustics data and DIDSON observations indicate that when releases are consistently large, a group of predatory fish is consistently observed near the release pipe. During the summer the number of predatory fish at the release site is significantly greater than the estimated population of predators in the remainder of the Horseshoe Bend area.

The principal hypothesis most important to this study was to test whether predation mortality within the local vicinity of the receiving waters is a significant contributor to overall mortality. A very simple bioenergetics approach was used to attempt to answer this question and suggests that the magnitude of predation on salvaged fish depends on how many salvaged fish are being released. Assuming an average weight of 13 g (0.028 lb) for each salvaged fish, if fish salvage numbers are less than 2,000 fish per release, which for this study occurred for all sampling periods other than August, then significant impacts of predation following release are likely. A group of predators at the release pipe could easily consume a significant portion of the biomass that is released, and certainly populations of fish are high enough in the open water areas around the SWP Horseshoe Bend release site to potentially equal this impact on a slightly longer time scale. Conversely, at certain times of the year (August) very high release numbers may actually swamp the population of predators in the area, and consequently in the short term result in a higher percentage of survivorship.

6.0 Synthesis

This study demonstrates that at the SWP Horseshoe Bend release site, predation on salvaged fishes may have a substantial impact on the number of fish that survive the complete salvage (CHTR) process. While major portions of this study specifically focused on predation at the SWP Horseshoe Bend release site, the study observations and results should still be applicable at the other state and federal release sites even though data collection efforts at these sites were not as intensive.

6.1 Predator Composition

Results of the electrofishing conducted at the SWP Horseshoe Bend release site revealed that various centrarchids and Sacramento pikeminnow were the predominant predators present within the vicinity of the release site. This was somewhat unexpected because anecdotal information and earlier studies (Pickard and others 1982) showed that striped bass were presumed to be the most likely predators at the salvaged fish release sites, but may be due to the fact that electrofishing was not conducted during the late-spring and early summer months when striped bass are common in the area. However, these results are consistent with other more recent studies that have shown centrarchids to be increasingly abundant in the delta and a major predator of juvenile and small adult fishes of the Delta (Brown and Michniuk 2007, Nobriga and Feyrer 2007). The increase in the abundance of centrarchids in the Delta has been attributed to the rapid and widespread colonization of invasive Brazilian waterweed *Egeria densa* and other invasive submerged plants (Brown 2003). This correlation was very clear during our sampling efforts when very few centrarchids were collected near the end of the SWP Horseshoe Bend release pipe, situated in open-water habitat, while centrarchids were collected in great numbers along the release site shoreline which was macrophyte dominated. One implication of this is that while largemouth bass may not be the predominant species aggregating at the release pipe, their sizable population in the region as indicated by our CPUE data suggests that they may still be an important predator on salvaged fish. That is to say, while salvaged fish might survive the initial exit from the release pipe, they may still be at risk of predation by largemouth bass as they disperse from the area. However, results of the bioenergetics modeling showed that striped bass could have a larger predation impact per fish due to their higher metabolic demands and feeding capacity. As a result, to develop a more conservative estimate of predation, one with the highest potential for predation losses, at the salvaged fish release sites, the consumption estimates for striped bass are favored.

Avian predation on salvaged fishes was observed at the SWP Horseshoe Bend release site. The avian predation observations showed that cormorants and gulls were the primary avian predators on salvaged fishes, and that they actively fed or scavenged during salvaged fish releases. When the salvaged fish are released, the water in the pipe is very turbulent. As fish pass through this area of turbulence and exit the pipe, they could be disoriented and become more susceptible to predation even though they may not be directly injured or killed by the release. Gulls were often observed picking at debris and dead or dying fish at the water surface, potentially including salvaged fish that may have become disoriented by the release. Furthermore, cormorants are efficient, deep water predators and were observed with the DIDSON chasing and capturing salvaged fish in the vicinity of the pipe outlet.

6.2 Predator Abundance

Predatory fish abundance based on hydroacoustic data was highest at Control Site 1 where a deep hole was located. Abundance at the SWP Horseshoe Bend release site was similar to Control Site 2. This finding suggests that on a coarse scale, releases at the Horseshoe Bend site do not appear to be influencing the abundance of predators. This is in contrast with the more fine scale DIDSON observations, however, which showed that abundance was typically highest at the SWP Horseshoe Bend release site when compared to the two control sites. Hydroacoustic data also showed peaks in abundance for all sites during the winter (third) monitoring period, with abundance lowest during the summer. Again in contrast, DIDSON observations showed that predatory fish abundance was highest during the summer and tapered off through the winter and early spring monitoring periods. These contrasting results suggest that at certain times of year the release site is not as attractive for predatory fishes even though there are substantial numbers of predatory fish in the area. This may be a result of several factors including a decreased metabolic demand for feeding due to low water temperatures, a more abundant source of food than the release sites (ie. a large population of bait fish in the area), or a small enough number of fish being released as to not make aggregating at the site energetically attractive.

Electrofishing catch data showed that the SWP Horseshoe Bend release site had a substantial population of largemouth bass. While the authors of this paper doubt that they represent a major source of the immediate predation on salvaged fish exiting the release pipe, their impact on the long term survival of salvaged fish cannot be discounted. Largemouth bass have been shown to be effective piscivores even at very small sizes (<110mm [4.3 in]; Nobriga and Feyrer 2007). Given their piscivorous nature and substantial population near the release site it is possible that while they may not feed directly on fish exiting the release pipe, the largemouth bass may feed on salvaged fish as the salvaged fish disperse following release.

Avian predators were consistently more abundant at the SWP Horseshoe Bend and CVP Emmaton release sites than either of the control sites or the SWP Curtis Landing release site. Interestingly, avian predator abundance increased during the winter and early spring periods even as the number of salvaged fish being release declined to very low levels.

Avian predation observations further supported the argument that even though predatory fish populations are lowest during the winter and early spring periods as indicated by DIDSON observations, the abundance of avian predators and relatively low salvage during this period results in the highest impact of predation on salvaged fish survival. Given the enormous food requirements of many avian predators (up to 1/3 body weight/day for cormorants), even a relatively small number of birds might have a substantial impact on the number of salvaged fish being lost to predation. Therefore, efforts should be taken to try and reduce predation by birds in addition to predatory fishes since even a minor reduction in avian predation may have a substantial effect on the number of salvaged fish being consumed.

6.3 Predator Behavior

Using acoustic telemetry, striped bass were shown to exhibit very little site fidelity. Tagged striped bass spent a very short amount of time near their location of tagging and migrated from the area rapidly. Sacramento pikeminnow, however, showed stronger site fidelity with some individuals remaining near a release site for months at a time. This is expected since Sacramento pikeminnow are known for their exploitation of artificial aggregations of prey fish such as those created by the release sites. While largemouth bass were not tagged with acoustic tags, they had the highest number of floy tagged fish recaptured, suggesting that they too exhibited strong site fidelity. This is consistent with other studies on largemouth bass which have shown that they have relatively limited ranges and do not have a life history (like that of striped bass) including long migrations to spawning, rearing, or feeding grounds.

Unfortunately, the acoustic telemetry equipment used in this study limited the ability to track the fine scale movement of predatory fish near the release sites, and limited the resolution to coarse scale presence or absence. Future studies should consider utilizing equipment with finer resolution to examine predator movement and behavior around the release sites which could potentially reveal predator utilization of particular habitat, structure, or areas which could be targets of management action for predator control. For example, DIDSON observations were able to reveal predators utilizing trapped debris around the Horseshoe Bend pipe support structure being used as refuge and cover.

DIDSON observations showed that predatory fish, when present, remain aggregated near the end of the release pipe for long periods of time. This was further supported by hyroacoustics data which showed many targets near the release site even during non-release periods. The DIDSON revealed that these prolonged aggregations were potentially a result of salvaged fish slowly exiting the release pipe long after the release was completed. Since predators remain aggregated in large numbers at the release site during non-release periods, efforts to detect any actions during the release process that might potentially serve as behavioral attractants (ie. a feeding bell) were unsuccessful. However, predators were occasionally observed becoming agitated or more active in response to various events during the release process such as the connection of the truck outlet to the release pipe or flushing pump activation.

Visual and DIDSON observations of avian predation confirmed that avian predators were effectively exploiting salvaged fish releases. On numerous occasions, gulls and cormorants were observed both visually and with the DIDSON, successfully capturing prey fish. DIDSON observations of cormorants showed that they actively chased and fed on salvaged fish, searching for prey near the end of the release pipe with ease. While the feeding cormorants were observed to occasionally scare predatory fish away, they were never observed actively pursuing the predatory fish, instead concentrating on capturing salvaged fish. Avian predators were also observed using a nearby agricultural intake as a resting site or perch between releases. As a result, a bird deterrent device at this site was installed as a potential way to reduce avian predation.

6.4 Magnitude of Predation of Salvaged Fish

The magnitude of potential predation occurring at the SWP Horseshoe Bend release site was strongly tied to the numbers of salvaged fish being released. DIDSON observations showed a strong positive correlation between the numbers of fish being salvaged and the predator abundance within the immediate vicinity of the release pipe. Furthermore, the results of bioenergetics modeling demonstrated that when the number of salvaged fish being released is <2,000 (assuming 13 g [0.028 lb] per fish), then the predatory fish population is capable of consuming a considerable portion of the biomass being released. Conversely, when the number of fish being released is very high, the predatory fish are effectively swamped relative to the number of released fish and their impact on salvaged fish mortality is consequently diminished. The presence of avian predators during the winter months further amplifies the magnitude of potential predation during the winter and early spring. One solution to this problem might be to release salvaged fish into net pens and accumulate a large number of fish prior to releasing them (assuming that salvaged predatory fish could be segregated from other salvaged fish). This might also be an effective way to reduce stress effects from the CHTR process as a whole (Portz 2007). By accumulating a large enough number of fish, the predator population might be swamped with the added benefit of less stressed and healthier fish.

The results of the bioenergetics modeling and hydroacoustics revealed an inherent weakness of DIDSON observations. Examination of DIDSON observations alone would most likely lead to an interpretation of significant predation during the summer when salvage is highest, and lower predation during other periods. This interpretation is a direct result of the DIDSON camera's very limited field of view and the resulting difficulty in accurately quantifying fish in a given area. The DIDSON failed to reveal, as the hydroacoustics did, that predator abundance in the region was actually highest at times of year when few if any predators were aggregated at the release pipe.

7.0 Recommendations

Based on the results of the various components of this study, the following actions and guidelines are recommended for improving current release operations and building new release sites:

1. Given the prevalence of centrarchids, especially largemouth bass, in the delta, all possible efforts should be taken to place release sites at locations that lack extensive centrarchid habitat (i.e., aquatic vegetations beds, submerged structure).

2. Releases during dawn and dusk, when predator activity was shown to be at its highest, should be avoided.

3. All possible roosting sites or perches near release sites should be either removed or equipped with bird deterrent devices (e.g., bird spikes). This measure, which has already been completed at the SWP Horseshoe Bend release site, would prevent avian predator species such as cormorants and gulls from perching on top of manmade structures near the release sites.

4. Release sites should be equipped with a screened flushing system pump to avoid entraining recently released fish.

5. Periodic removal of underwater debris in the immediate vicinity of the release pipes should be conducted. This measure, which is being planned for the SWP Horseshoe Bend release site, would prevent the creation of predatory fish habitat. Release site designs should also minimize the amount of underwater structure such as support pilings to reduce debris accumulation.

6. Release pipes should be flushed more effectively to prevent predators from aggregating at the pipe to feed on fish slowly trickling from the release pipe. Modifications to the SWP release sites are currently underway to address this issue using hydraulic guidelines developed from the Element 3 investigation.

8.0 Future Research Questions

This study uncovered a number of topics that could benefit from further research. Research on these topics could lead to further recommendations or guidelines to reduce predation on salvaged fish.

1. What is the feasibility of using net pens or an alternate holding and release process to release salvaged fish?
    - The use of net pens or an alternate holding strategy might reduce the effects of predation by allowing releases of larger numbers of fish, effectively overwhelming the receiving water predator pool. This additional acclimation time would also have the benefit of reducing salvaged fish stress.

2. What is the efficacy of various behavioral deterrent measures such as strobe lights, sound barriers, bubble curtains and electrical barriers in preventing aggregations of predators at the salvaged fish release sites? How do various species of predators respond to these different measures?
    - Behavioral deterrent devices could help to reduce near-field predation on salvaged fish and give salvaged fish a chance to disperse from the immediate vicinity of the release site (reducing their short term susceptibility to predation at release). Any investigations on behavioral deterrents should be targeted at all the major predatory fish species encountered during the study (striped bass, largemouth bass, Sacramento pikeminnow).

3. How long do predators remain aggregated near release sites after regular releases are stopped? How would alternate release site rotations influence the buildup of predators at a release site?
    - By determining how long predators remain aggregated at a release site post release, it might be possible to determine an appropriate "resting" period for release sites. This could also lead to a recommendation for the total number of release sites necessary to use release site rotation as a predation management measure.

4. What is the impact of predation by centrarchids on the mortality of salvaged fish?
    - While centrarchids were captured in substantial numbers at each of the sites monitored, their actual impact on salvaged fish survival was difficult to determine because they were typically captured along the shoreline near the release sites, not at the end of the release pipes. By examining their gut contents versus the gut contents of centrarchids at other areas in the delta, it may be possible to determine if the centrarchids at the release sites display a higher level of piscivory indicative of predation on salvaged fish.

Alternatively, modern acoustic tags and 2d or 3d telemetry tracking systems could be used to determine how centrarchids respond to salvaged fish releases.

5. What would the impact of increased predatory fish harvest at a release site be on the release site predator population? Would improved public fishing access at release sites be an effective method of controlling predatory fish accumulation?
    - Improved public fishing access at the release sites could be a way to minimize predator accumulation by direct harvest and removal of predatory fish.

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Weather Underground
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11.0 Appendices

11.1 VEMCO Technology

VEMCO VR2 monitoring receivers and VEMCO coded transmitters were used 1) for their relatively low cost and 2) because of the wide array of VR2 receivers deployed throughout the Delta for other studies. The latter made possible tracking Element 2-tagged fish beyond the study's boundaries. Two different sizes of VEMCO transmitters were used for this study: the V9-1L and the V13-1L. The V9-1L transmitter dimensions were 9 mm (0.35 in) in diameter by 21 mm (0.82 in) length. The tags weighed 2.2 g (0.08 oz) in water (3.6 g [0.13 oz] in air) and produced a power output of 142 dB re 1μPa at 1 meter. The larger V13-1L transmitter dimensions were 13 mm (0.5 in) in diameter by 36 mm (1.4 in) length. The tag weighed 6 g (0.2 oz) in water (11 g [0.4 oz] in air) and produced a power output of 147 dB re 1μPa at 1 meter. Each transmitter was powered by an internal silver-oxide battery that was turned on or off by a magnetic switch. The magnetic switch was controlled by a small magnet that adhered to the surface of the tag. The tags became active when the user removed the magnet. Transmitter parameters were set and secured at the factory. Each transmitter (battery and electronics) was sealed with epoxy in a cylindrical casing. Battery life varied with transmitter size and custom parameters, such as delay between signal transmission.

When a transmitter was turned on by removing its external magnet, it emitted 3 rapid pings. Then the transmitter entered a start-up phase, which contained 16 strings of 7 pings each. The transmitter pinged 7 times, waited about 2 seconds, pinged 7 times, waited 2 seconds, and repeated this process 16 times. After this start-up phase, the 2-second delay was replaced by the factory-set delay.

Each transmitter had a unique code and emitted acoustic pulses or pings at a frequency of 69 kHz. Transmitter identification was coded as binary data into the intervals between a burst of pulses (Pincock 2008). Pulse width and interval were controlled by a microprocessor within the transmitter. The number of intervals and pulses required to contain the entire identification varied depending on the transmitter-coding scheme. The first pulse in the series or group had a fixed width and was for synchronizing with the receiver (Ryan Mayfield, personal communication). Additional pulses and intervals followed, completing the transmission.

VEMCO created a variety of different transmitter coding schemes in an effort to produce more, unique identifying codes. Transmitters used in this study were of the coding scheme R04K, which contained 6 intervals and was referred to as code space A69-1206. The code (identification) was contained within the 7 pings. The first ping was of fixed-length and was provided for synchronization purposes. The remaining 6 pings encoded the transmitter identification and error checking capabilities.

The group of intervals and pulses were followed by a period of delay, or silence. The delay period was random and was not less than the minimum off time and not more than the maximum off time, parameters that were set at the time of manufacture. For all but 3 tags used in this study, the delay was 40 to 120 seconds. For tag numbers 1385, 1386, and 1387, the delay was 20 to 60 seconds. The purposes of the delay were to 1) conserve battery life and 2) make possible for complete detection of multiple transmitters near a single receiver. The random delay also ensured that 2 or more tag signals would not continuously collide with each other. Collisions between tag signals might have occurred when two or more tags transmitted its signal simultaneously.

VEMCO VR2 receiver parameters and components were created and sealed in a cylindrical casing at the factory. Receiver noise-filtering and tag detection algorithms were set by VEMCO and cannot be adjusted by the user. VEMCO VR2 receivers were designed with detection algorithms to measure the time interval between transmitted pulses. Valid detections occurred when the receiving algorithm detected pulses with intervals of those used in the coding scheme. The receiver was designed to reject transmission intervals smaller or larger than expected. However, a false detection might have occurred if (1) the pulse intervals were valid lengths (time intervals) or (2) the error detection algorithm failed to detect the transmission error. Pincock (2008b) stated that a single detection of a transmitter could indicate a false detection. As a conservative approach during this study, detections of ≤ 2 per receiver per hour were considered to be false detections.

Receivers were deployed during this study in areas where detection capabilities might have been affected by broadband noise. The VR2's preamplifier could have been affected by noise within the bandwidth of the preamplifier, around 20 kHz to 100 kHz (Pincock 2008a). As a result, VR2 detection performance could have been affected by ambient noise and by biological or man-made sounds. The effects of weather also may have altered the detection range of this study's receivers. Therefore, the detection range could have varied throughout the study period. Specifically, receiver performance could have decreased in conditions of poor weather or significant noise.

The VR2 receiver produced a file output (statistics) with every download. This file output contained the following information:

1. *Checksum invalid*: number of almost-complete detections rejected by the receiver's algorithm
2. *Total syncs*: number of correct sync values received (sync = time between the first 2 pings of a coded tag's transmission

3. *Total detections*: number of complete coded ping trains received and accepted.
4. *Total pulses received*: number of every acoustic ping detected by the receiver

The information above may be used to calculate detection efficiency of the receiver. A low efficiency may indicate a lot of noise in the environment or collisions from multiple tags.

11.2 Validation of Acoustic Doppler Velocimeter

On July 19, 2007 a comparison test of flow velocity using a propeller and an ADV velocity meter was performed. The comparison test was conducted to determine if an upward viewing ADV could be used in a downward orientation and still maintain instrument accuracy. The calibrated propeller meter was used as an accuracy check for the ADV. The ADV was not tested in the calibration flume because the size of the flume did not facilitate testing. It was too shallow to allow for proper operation of the ADV unit.

Methodology

Calibration of Propeller Velocimeter

Prior to the comparison test, the Swoffer 2100 velocimeter was tested for accuracy at the UCD Hydraulics lab small instrument calibration facility. The velocimeter was positioned inside a calibration chamber and a series of flows with water velocities (30.5, 45.7, 61, 76.2, and 91.4 cm/s [1, 1.5, 2.0, 2.5, and 3.0 ft/s]) were introduced into the chamber. For each type of flow, ten propeller velocity readings were recorded. These test velocities were selected because they are representative of velocities in the field. The duration interval for each propeller reading was set for 90 seconds.

Field Test Using ADV and Propeller Velocimeter

Equipment

- Argonaut-ADV SW in downward viewing position
- Swoffer 2100 propeller velocimeter
- 3.35 m (11 ft) aluminum mounting pole for swoffer velocimeter
- Aluminum Jet Boat
- Lowrence depth finder

Test Sites

Velocity readings were taken at three different locations at and near Horseshoe Bend just off of Sherman Island. The three sites are as follows: CHTR element 2 control site number two, the SWP Horseshoe Bend fish release site, and the CVP Emmaton fish release site. The sites were selected as test sites because they will be used as monitoring sites during the CHTR element 2 studies.

Test Set-Up

The ADV unit was deployed over the side of the boat and suspended by two chains. The Unit was set horizontal to channel bottom. The distance from the water surface to the ADV viewable depth was approximately 1 m (3.2 ft) (viewable depth is the initial point away from the face of the unit that velocity readings are taken). Water depth at all locations was attained using the boat mounted Lawrence sonar/gps system. The Swoffer 2100 velocimeter was mounted to a 3–meter (10–foot) length of aluminum pipe for elongation of the unit and structural support. The total length of the pipe w/velocity probe was 3.35 m

(11 ft). The pipe was labeled in 0.3 m (1 ft) increments and the orientation of the propeller marked at the distal end of the pipe. Both the ADV and Swoffer units were set to sample over a 90 second interval (max interval for the Swoffer).

At each site the boat was stationed parallel to the shoreline by attaching to two piles, placing the boat was reasonably parallel to the flow. The tide was outgoing for all sampling.

Data Collection

Water depth at the test sites varied. At each site the depth to the channel bottom was determined using the boat mounted sonar unit. The ADV was then set to scan this water depth minus 1 m, to account for the depth of the ADV unit and the distance at which it begins to scan for data. The propeller probe was deployed at the midway point of the ADV scanning distance for each individual site. At the CVP Emmaton release site the ADV was set to a scanning distance of 4.8 m (15.7 ft) (the maximum range for the unit). This site is much deeper than the other test sites. The Swoffer and ADV units were set to the same sampling orientation. Then 10 velocities were recorded using each of the unit simultaneously.

Data/Results

Calibration Data

Calibration Data for Swoffer Propeller Velocimeter
U.C. Davis Hydraulics Facility **6/13/07**
90 s sample interval

Flume velocity (Vf)	Measured Velocity (Vm)
(Target velocity = 1.0ft/sec)	
0.99	1.1
0.99	1.11
0.99	1.1
0.99	1.1
0.99	1.1
(Target velocity = 1.5ft/sec)	
1.51	1.72
1.51	1.73
1.51	1.72
1.51	1.73
1.51	1.72
(Target velocity = 2ft/sec)	
2.01	2.33
2.01	2.33
2.01	2.33
2.01	2.33
2.01	2.32
2.01	2.32
(Target velocity = 2.5ft/sec)	
2.5	2.98

2.5	2.98
2.5	2.97
2.5	2.98
2.5	2.96
.52	2.96
(Target velocity = 3ft/sec)	
3.01	3.61
3.01	3.61
3.01	3.61
3.01	3.61
3.01	3.6

Results of the comparison test at the UCD Hydraulics Lab showed a difference in velocity readings between the velocimeter and calibration flume. An equation was developed to account for the difference in velocity between the two instruments. This equation would then be used to correct field data collected with the propeller probe. The equation is as follows:

$$y = 0.8021(x) + 0.1222 \qquad \text{Eq. (A.1)}$$

Where y = corrected velocimeter reading
x = measured velocimeter reading

Data collected in the field with the ADV unit was compared to velocity propeller probe readings for accuracy. The velocity readings were first corrected using equation A.1. The corrected velocity readings were then compared to the ADV readings for accuracy. Results showed logarithmic relationship in the velocity readings between the velocimeter and ADV unit. An equation was developed to account for the difference in velocity readings and obtain an adjusted ADV velocity. The formula is as follows:

$$y = 0.9944*\ln(x) + 0.983 \qquad \text{Eq. (A.2)}$$

Where y = adjusted ADV velocity
x = measured ADV velocity

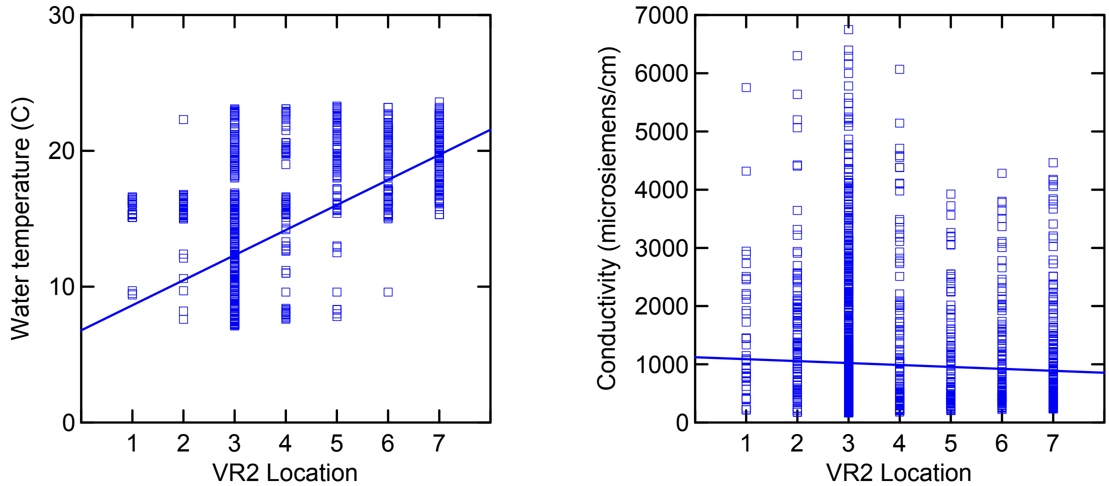
All field ADV data was corrected using this equation.

Results

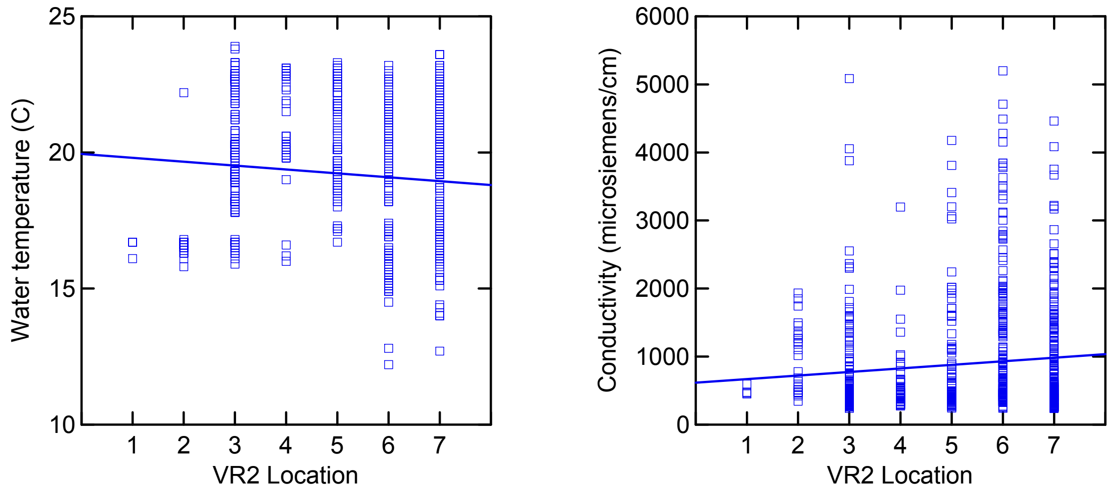
The ADV adjusted velocity readings (using eq. A.2) correlated well with the propeller probe true velocity readings. In water velocities ranging from 29.87 cm/s to 60 cm/s (0.98 ft/s to 1.97 ft/s), the difference between the propeller and adjusted ADV readings was between 0.0 cm/s to 3.05 cm/s (0.0 ft/s to 0.1 ft/s).

11.3 Movement of acoustic-tagged Sacramento pikeminnow plotted against water temperature

Sacramento pikeminnow Tag # 3425



Sacramento pikeminnow Tag # 3426

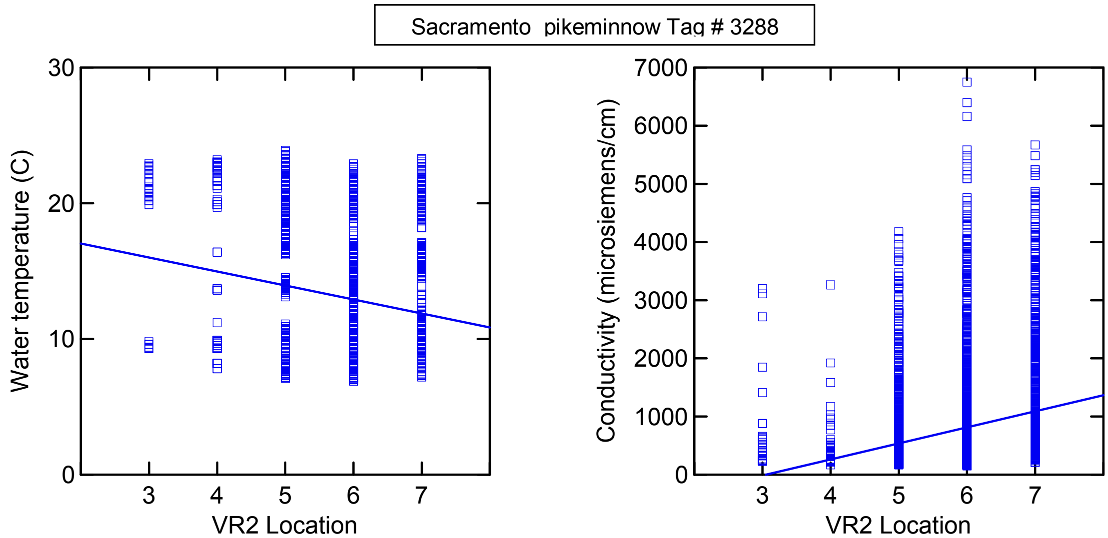


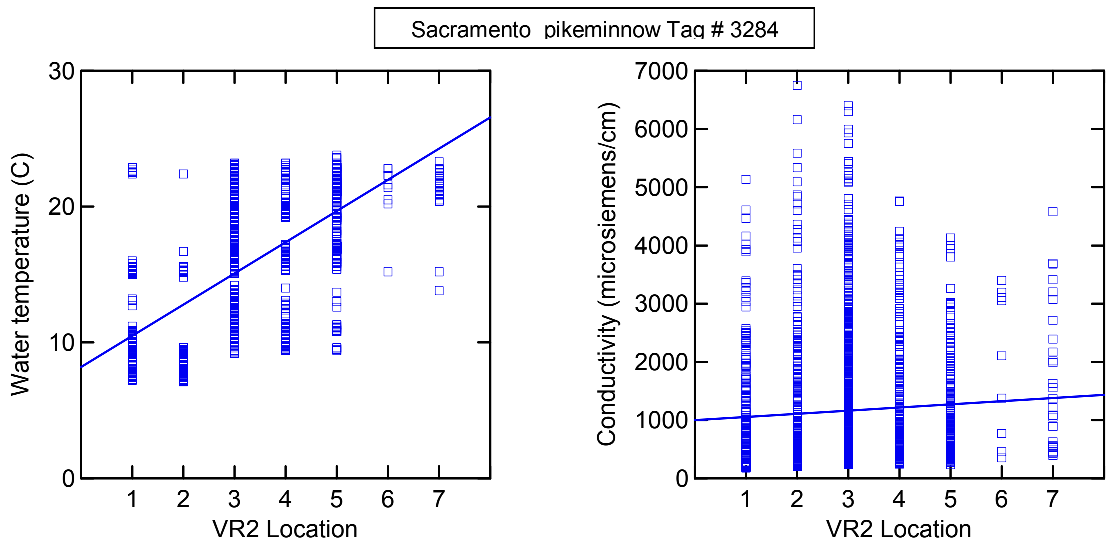
VR2 Location

1 Sacramento River downstream of Emmaton release site
2 USBR Emmaton release site
3 DWR Horseshoe Bend release site
4 Midway between Horseshoe Bend release site and Conrol Site 1
5 Control Site 1
6 Control Site 2
7 Decker Island north of Control Site 2

1 = Furthest downstream site 7 = Furthest upstream site

11.4 Movement of acoustic-tagged Sacramento pikeminnow plotted against water temperature and conductivity





<u>VR2 Location</u>

1 Sacramento River downstream of Emmaton release site
2 USBR Emmaton release site
3 DWR Horseshoe Bend release site
4 Midway between Horseshoe Bend release site and Conrol Site 1
5 Control Site 1
6 Control Site 2
7 Decker Island north of Control Site 2

1 = Furthest downstream site 7 = Furthest upstream site

11.5 Acoustic data analyses and processing

Analyses of acoustic data consisted of a series of steps, designated as

a) Observation
b) Calibration and Thresholding
c) Regions for Exclusion (Noise)
d) Echo Extraction
e) Trace Formation (Fixed Station)
f) Output Formatting/Quality Assurance

a) Observation

Acoustic files were 1 hour in length, for the fixed site and 30 minutes in length during mobile surveys. Files were broken down in this manner to avoid complete data loss should a computer system crash. Files were visualized by “play-back” in Echo View, providing a high-resolution color echogram of the file. Comments were recorded on presence of fish targets, as well as regions overshadowed by acoustic interference. The primary source of acoustic interference was volume reverberation from bubbles produced by wind generated waves, boat wakes, small debris in the water, and interference as one edge of the acoustic beam contacts the river substrate or surface air-water interface (Figure A1).

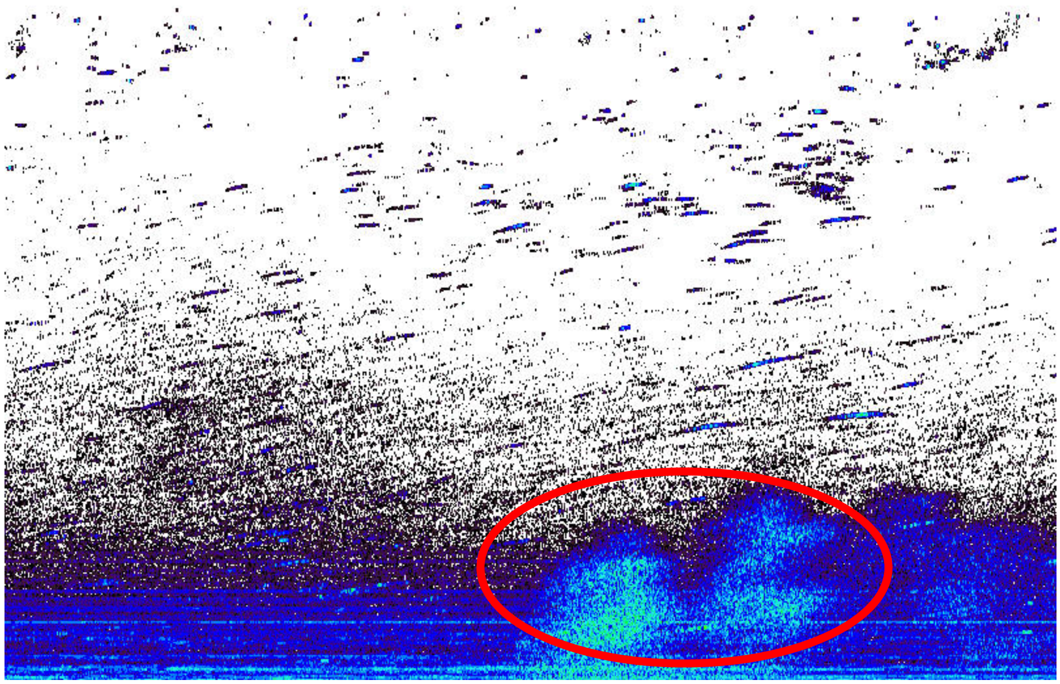


Figure A1- Snapshot of acoustic echogram showing two sources of noise. The light blue bands across the bottom of the picture represent range limitation with the edge of the transducer beam contacting either the surface or bottom. The blue cloud, circled in red, represents the wake from a passing boat.

b) Calibration and Thresholding

Calibration consisted of entering data on water temperature (used for speed of sound calculation), and acoustic system information including, beam angle, frequency, and range gates for analysis. Thresholding was used to limit as much noise as possible. Much of the volume reverberation was observed at a relatively low level. Data files were collected using a -70 dB. Since this level is considerably less than the acoustic size of fish targets the data was Thresholded further for analysis, setting a lower limit for targets at -45 dB for fixed site and down looking mobile data and -40 dB for side looking mobile data. Side looking mobile data had a higher threshold due to almost continuous wave action in the area entraining micro-bubbles near the surface, this was not a problem for the fixed side looking units due to their depth below the water surface. This Thresholding process removed a considerable amount of the acoustic interference, allowing a more rigorous evaluation of the acoustic data. The above parameters, once set, were then saved as a template to automate importation of additional data sets.

c) Exclusion of Bad Data

Even with the increased threshold, some regions were masked by high noise events, and no fish data could be recovered from these regions. Polygons can be drawn on the data field screen with the mouse to denote areas of exclusion, or as is the case with the side-looking mobile data the maximum data range was adjusted throughout the file by manually placing a line in the file, beyond which all data is excluded. For mobile data, boat wakes, wave action, and the impact of varying water depths impacted the range to which data could be analyzed. Fixed site data was typically only range limited due to bottom intrusion, or a large piece of debris fixed in the river bottom

d) Echo Extraction

Pulse width was used as a primary filter to test the returning wave shape. Echoes from reverberation should have corrupted wave shapes in comparison to point-source target echoes (small fish). The pulse width was measured at the half amplitude (endpoint criteria = -6 dB). The pulse width measurement was compared to the nominal transmitted shape (0.4 ms). Echoes with pulse width measurements less than 0.5 times the nominal or greater than 1.5 times the nominal were rejected. The next filter is the maximum allowable beam compensation. This puts a limit on how far off the center axis of the transducer beam a target can be. For these analyses the level was set to 10 dB. A target could be 10 db off peak and still be included in the analysis. The further off the beam axis a target is past a certain point, the less reliable the estimate of size and position are. The final step is to examine the standard deviation of the angles of the samples in both the x and y range. Samples that fall outside the specified range were be rejected.

Once a target has been defined and accepted, the target is utilized in one of two ways. For mobile surveys the targets are the primary mode of analyses, whereas with fixed stations targets are then subject to the formation of fish tracks in the following section.

e) Trace Formation (Release site only)

This process is often called fish tracking. Trace formation is 4-dimensional, using time and the X/Y/Z position produced by a split-beam system. EchoView's Fish Tracker implements a fixed coefficient filtering method as presented in Blackman (1986). The filtering process selects out single targets as candidates for a track. The algorithm is applied to data from a single target detection process. These are implemented as the 4D and 2D algorithms for split beam data (i.e. targets with range, angles and time). The sensitivity of the tracker to unpredicted changes in position and velocity is controlled by the Alpha and Beta gains respectively. Each fish echo that has passed the echo extraction tests is characterized by a ping number (time) and range. These provide X and Y coordinates. When a candidate echo is received, the algorithm “opens” a new trace. The range of this first seed echo is projected horizontally. A “tracking window” is centered about this position to provide a range window in the following ping. Any echo inside this range window must by definition be correlated to the seed echo. If multiple echoes fall inside the window, a best fit is calculated and that echo is linked to the original seed echo, providing a fish trace containing two echoes. Again, the echo that is closest to the center of the window is selected to be linked to the growing fish trace. A maximum range can be specified, outside of which echoes will not be included. This is useful when fish are close together to avoid the track jumping from fish to fish. A “ping gap” value is entered by the user to define when the trace is completed. If a gap of four is entered, then an active fish trace may miss three echoes and still search for candidate echoes. When the fourth echo is missed, the trace is completed and passed on to the trace filtering processes. In the final stage the length of the track is specified. Having more targets in a track generally results in a more reliable track. Fish tracking can further be used as a way to ignore some background noise as well, as only accepted fish tracks are used in the analysis thus eliminating some of the single targets generated due to noise.

f) Output Formatting and Quality Assurance

For target analyses only each target, instead of trace, is recorded as a date, location range and size. The trace formation process produces a data file with a line (record) for each fish trace accepted by the trace filtering. Each trace is coded by date, time, and contains some trace information such as mean target strength and range, and number of echoes. For split-beam, in addition, angular data such as off axis distances, velocity, and direction of travel are acquired. The direction of travel is calculated as an angle varying between 0 and 360º. The split-beam coordinate system may be considered as a compass, with north oriented in the direction opposite the cable connector on the transducer. This direction would represent 0 degrees. A clockwise rotation of 90 degrees would indicate a direction corresponding to East. Depending on how the transducer was mounted, the direction column indicates the vector direction in a plane normal to the acoustic axis, with zero degrees opposite the connector. Thus a fish with direction of between 0.1 degrees and 179.99 degrees would be considered as going from left to right across the transducer face. For this study any graphics where direction of travel is indicated, 0–179.99 degrees indicate fish are moving upstream in the direction of Rio Vista. Typically observations for a fish are near 90 or near 270 degrees (straight upstream, or straight downstream. An average movement near 180 degrees is indicative of no directional preference.